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In the assessment of community air pollution, there is a critical need for accurate data on the quantity and characteristics of emissions from the numerous sources that contribute to the problem. The large number of individual sources and the diversity of source types make conducting field measurements of emissions on a source-by-source basis at the point of release impractical. The only feasible method of determining pollutant emissions for a given community is to make generalized estimates of typical emissions from each of the source types. One of the most useful (and logical) tools for estimating typical emissions is the 'emission factor,' which is an estimate of the rate at which a pollutant is released to the atmosphere as a result of some activity, such as combustion or industrial production, divided by the level of that activity (also expressed in terms of a temporal rate). In other words, the emission factor relates the quantity of pollutants emitted to some indicator (activity level) such as production capacity, quantity of fuel burned, or vehicle miles t,....

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AP-42

SUPPLEMENT 9

SUPPLEMENT NO. 9
FOR

COMPILATION
OF AIR POLLUTANT
EMISSION FACTORS,
THIRD EDITION
(INCLUDING SUPPLEMENTS 1-7)

LIMITED
PREVIEW EDITION

March 1979

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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Preface to This

LIMITED PREVIEW EDITION

In view of the extensive time required to edit, compose, assemble and print AP-42 supplements, it has been decided to use this approach to provide the important technical information of AP-42 as soon as possible to those who require it. The formal version will be undergoing production as this preview edition is being used. Interested persons may obtain Supplement 9 or any past or future printings by using the enclosed form or by writing or telephoning the document project officer:

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Upon receipt of a formal version of Supplement 9, this preview version should be discarded.

Review comments, corrections or suggestions toward improving AP-42 and making it more useful are earnestly invited. As the title indicates, AP-42 is a compilation of material and data from many and varied sources. Therefore, any available information that could be considered in developing precise and reliable emission factors or revisions of those already in this document should be brought to the attention of the project officer above.

SPECIAL NOTE

As the mailing and distribution schemes for AP-42 and related materials must be regularly updated, anyone wishing to continue receiving such information must complete and return the form bound into this publication. Failure to do so will impede your obtaining AP-42 and emission factor publications in the future.

COMPILATION OF AIR POLLUTION EMISSION FACTORS

INTRODUCTION

In the assessment of community air pollution, there is a critical need for accurate data on the quantity and characteristics of emissions from the numerous sources that contribute to the problem. The large number of individual sources and the diversity of source types make conducting field measurements of emissions on a source-by-source basis at the point of release impractical. The only feasible method of determining pollutant emissions for a given community is to make generalized estimates of typical emissions from each of the source types.

One of the most useful (and logical) tools for estimating typical emissions is the "emission factor," which is an estimate of the rate at which a pollutant is released to the atmosphere as a result of some activity, such as combustion or industrial production, *divided by* the level of that activity (also expressed in terms of a temporal rate). In other words, the emission factor relates the quantity of pollutants emitted to some indicator (activity level) such as production capacity, quantity of fuel burned, or vehicle miles traveled. In most cases, these factors are simply given as statistical or estimated averages; that is, no empirical information on the various process parameters (temperature, reactant concentrations, etc.) is considered in their calculation. However, for a few cases, such as in the estimation of hydrocarbon emissions from petroleum storage tanks, precise empirical formulas relating emissions to such variables as tank diameter, liquid storage temperature, and wind velocity have been developed. Because of their superior precision, emission factors based on empirical formulas are more desirable to obtain and can usually be given the highest accuracy rating. Factors derived from statistical averages, however, if based on an adequate number of field measurements ("source tests"), can also be both precise and accurate within practical and useful limits.

An example should illustrate how the factors are to be used:

Suppose a sulfuric acid plant, with a production rate of 200 tons/day of 100 percent acid, operates at an overall SO_2 to SO_3 conversion efficiency of 97 percent. Using the formula given as a footnote to Table 5.17-1 of this publication, the *uncontrolled* sulfur dioxide emissions can be calculated:

SO_2 emissions = [-13.65 (%conversion efficiency) + 1365] × production rate
= [-13.65 (97%) + 1365] lb/ton acid × 200 tons acid/day
= 40 lb/ton acid × 200 tons acid/day
= 8000 lb/day (3632 kg/day)

The emission factors presented in this report have been estimated using a wide spectrum of techniques available for their determination. The preparation/revision of each factor section involves, first of all, locating and obtaining all the known written information on that source category from such sources as available literature, Environmental Protection Agency technical reports (including emission test reports), and the National Emissions Data System point source file. After these data are reviewed, organized, and analyzed, the process descriptions, process flowsheets, and other background portions of the section are prepared. Then, using the compiled information, representative emission factors are

developed for each pollutant emitted by each point source of the process category. As stated above, these factors are usually obtained by simply averaging the respective numerical data obtained. When feasible, the ranges in the factors are presented for further clarity. Occasionally, enough data exist to permit the development of either empirical or theoretical formulas (or graphs) relating emission factors to various process parameters such as stream temperature, sulfur content, or catalyst. In these cases, *representative* values of these process parameters are selected and substituted into the formulas or graphs to obtain representative emission factors, which are then tabulated. The pertinent formulas and graphical data are also included in the section to allow the estimation of emission factors when the process conditions differ from those selected as representative.

After the draft of a section is completed, it is circulated for technical review to various personnel routinely familiar with the emission aspects of the particular activity. After these review comments are obtained and evaluated, the final draft is written and submitted for editing and publication.

The limitations and applicability of emission factors must be understood. To give some notion of the accuracy of the factors for a specific process, each set of factors has been ranked according to the available data upon which it was based. Each rank was based on the weighting of the various information categories used to obtain the factor(s). These categories and associated numerical values were:

Measured emission data: 20 points, maximum.
Process data: 10 points, maximum.
Engineering analysis: 10 points, maximum.

The emission data category rated the amount of measured (source test) data available for the development of the factor. The process data category involved such considerations as the variability of the process and its resultant effect on emissions, as well as the amount of data available on these variables. Finally, the engineering analysis category was concerned with the data available upon which a material balance or related calculation could be made.

Depending on which information categories were employed to develop it, each set of factors was assigned a numerical score, ranging from 5 to 40. For example, if the factors developed for a certain process were based on a large number of source tests, a moderate amount of process data, and no engineering analysis work, the assigned score would be 20 + 5 = 25.

Each numerical score was, in turn, converted to a letter rank as follows:

Numerical Rank	*Letter Rank*
5 or less	E(Poor)
6 to 15	D(Below average)
16 to 25	C(Average)
26 to 35	B(Above average)
36 to 40	A(Excellent)

These rankings are presented below the table titles throughout this publication.

The reader must be cautioned not to use these emission factors indiscriminately. That is, the factors generally will not permit the calculation of accurate emissions measurements from an individual installation. Only an on-site source test can provide data sufficiently accurate and precise to use in such undertakings as design and purchase of control equipment or initiation of a legal action. Factors are more valid when applied to a large number of processes, as, for example, when emission inventories are conducted as part of community or nationwide air pollution studies.

LIMITED PREVIEW EDITION
of
SUPPLEMENT 9 OF AP-42

Section	Title	Change
1.11	Waste Oil Disposal	new
4.4	Transportation and Marketing of Petroleum Liquids	minor revision
4.5	Cutback Asphalt, Emulsified Asphalt and Asphalt Cement	new
4.6	Solvent Degreasing	new
5.2	Synthetic Ammonia	major revision
5.3	Carbon Black	major revision
5.22	Lead Alkyl	new
6.13	Bread Baking	new
6.14	Urea	new
6.15	Beef Cattle Feedlots	new
6.16	Defoliation and Harvesting of Cotton	new
7.3	Primary Copper Smelting	fugitive factors
7.6a	Leadbearing Ore Crushing and Grinding	new
7.9	Secondary Copper Smelting and Alloying	fugitive factors
7.15	Storage Battery Production	new
7.16	Lead Oxide and Pigment Production	new
7.17	Miscellaneous Lead Products	new
8.10	Concrete Batching	fugitive factors
10.4	Woodworking Operations	fugitive factors
Appendix E	Table of Lead Emission Factors	new

1.11 WASTE OIL DISPOSAL

by Jake Summers, EPA,
and Pacific Environmental Services

1.11.1 General

The largest source of waste oil is used automotive crankcase oil, originating mostly from automobile service stations, and usually being found with small amounts of other automotive fluids. Other sources of waste oil include metal working lubricants, heavy hydrocarbon fuels, animal and vegetable oils and fats, and industrial oil materials.

In 1975, 57 percent of waste crankcase oil was consumed as alternative fuel in conventional boiler equipment (Section 1.3). The remainder was refined (15 percent), blended into road oil or asphalt (15 percent), or used for other nonfuel purposes (13 percent).[1]

1.11.2 Emissions and Controls

Lead emissions from burning waste oil depend on the lead content of the oil and on operating conditions. Lead content may vary from 800 to 11,200 ppm.[2] Average concentrations have been suggested as 6,000[1] and as 10,000 ppm[3]. During normal operation, about 50 percent of the lead is emitted as particulate with flue gas.[2,4] Combustion of fuel containing 10 percent waste oil gives particulate ranging from 14 to 19 percent lead. Ash content from combustion of fuels containing waste oil is higher than that for distillate or residual fuel oil, ranging from 0.03 to 3.78 weight percent, and lead accounts for about 35 percent of the ash produced in such combustion.[2]

Currently, controls are not usually applied to oil fired combustion sources. An exception is utility boilers, especially in the northeastern United States. Pretreatment by vacuum distillation, solvent extraction, settling and/or centrifuging minimizes lead emissions but may make waste oil use uneconomical.[2] High efficiency

particulate control by means of properly operated and maintained fabric filters is 99 percent effective for 0.5-1 um diameter lead and other submicron-sized particulate, but such a degree of control is not much used.[2]

Table 1.11-1. WASTE OIL COMBUSTION EMISSION FACTORS
(EMISSION FACTOR RATING: B)

Pollutant	Emission Factor		References
	(kg/m^3)	($lb/10^3 gal$)	
Particulate[a]	2.3	19	6
Lead[b]	4.8 (P)	40 (P)	1,2,3,5

[a]For virgin oil. Particulate emissions vary according to type of boiler and grade of fuel burned. Refer to Section 1.3, Table 1.3-1 for specific emission factors for fuel oil combustion.

[b]The letter P indicates that the percent lead in the waste oil being processed should be multiplied by the value given in the table in order to obtain the emission factor. Average P = 1.0 percent (10,000 ppm). Refer to Reference 6.

References for Section 1.11

1. S. Wyatt, et al., Preferred Standards Path Analysis on Lead Emissions from Stationary Sources, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1974.

2. S. Chansky, et al., Waste Automotive Lubricating Oil Reuse as a Fuel, EPA Contract No. 68-01-1859, U.S. Environmental Protection Agency, Washington, DC, September 1974.

3. Final Report of the API Task Force on Oil Disposal, American Petroleum Institute, New York, NY, May 1970.

4. Background Information in Support of the Development of Performance Standards for the Lead Additive Industry, EPA Contract No. 68-02-2085, PEDCo-Environmental Specialists, Inc., Cincinnati, OH, January 1976.

5. Emission Tests Nos. 71-CI-08 and 71-CI-09, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1971.

6. Control Techniques for Lead Air Emissions, EPA-450/2-77-012, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1977.

4.4 TRANSPORTATION AND MARKETING OF PETROLEUM LIQUIDS[1]

Audrey McBath

4.4.1 Process Description

As Figure 4.4-1 indicates, the transportation and marketing of petroleum liquids involves many distinct operations, each of which represents a potential source of hydrocarbon evaporation loss. Crude oil is transported from production operations to the refinery via tankers, barges, tank cars, tank trucks, and pipelines. In the same manner, refined petroleum products are conveyed to fuel marketing terminals and petrochemical industries by tankers, barges, tank cars, tank trucks, and pipelines. From the fuel marketing terminals, the fuels are delivered via tank trucks to service stations, commercial accounts, and local bulk storage plants. The final destination for gasoline is usually a motor vehicle gasoline tank. A similar distribution path may also be developed for fuel oils and other petroleum products.

4.4.2 Emissions and Controls

Evaporative hydrocarbon emissions from the transportation and marketing of petroleum liquids may be separated into four categories, depending on the storage equipment and mode of transportation used:

1. Large storage tanks: Breathing, working, and standing storage losses.
2. Marine vessels, tank cars, and tank trucks: Loading, transit, and ballasting losses.
3. Service stations: Bulk fuel drop losses and underground tank breathing losses.
4. Motor vehicle tanks: Refueling losses.

(In addition, evaporative and exhaust emissions are also associated with motor vehicle operation. These topics are discussed in Chapter 3.)

4.4.2.1 Large Storage Tanks - Losses from storage tanks are thoroughly discussed in Section 4.3.

4.4.2.2 Marine Vessels, Tank Cars, and Tank Trucks - Losses from marine vessels, tank cars, and tank trucks can be categorized into loading losses, transit losses, and ballasting losses.

Loading losses are the primary source of evaporative hydrocarbon emissions from marine vessel, tank car, and tank truck operations. Loading losses occur as hydrocarbon vapors residing in empty cargo tanks are displaced to the atmosphere by the liquid being loaded into the cargo tanks. The hydrocarbon vapors displaced from the cargo tanks are a composite of (1) hydrocarbon vapors formed in the empty tank by evaporation of residual product from previous hauls and (2) hydrocarbon vapors generated in the tank as the new product is being loaded. The quantity of hydrocarbon losses from loading operations is, therefore, a function of the following parameters:

- Physical and chemical characteristics of the previous cargo.
- Method of unloading the previous cargo.

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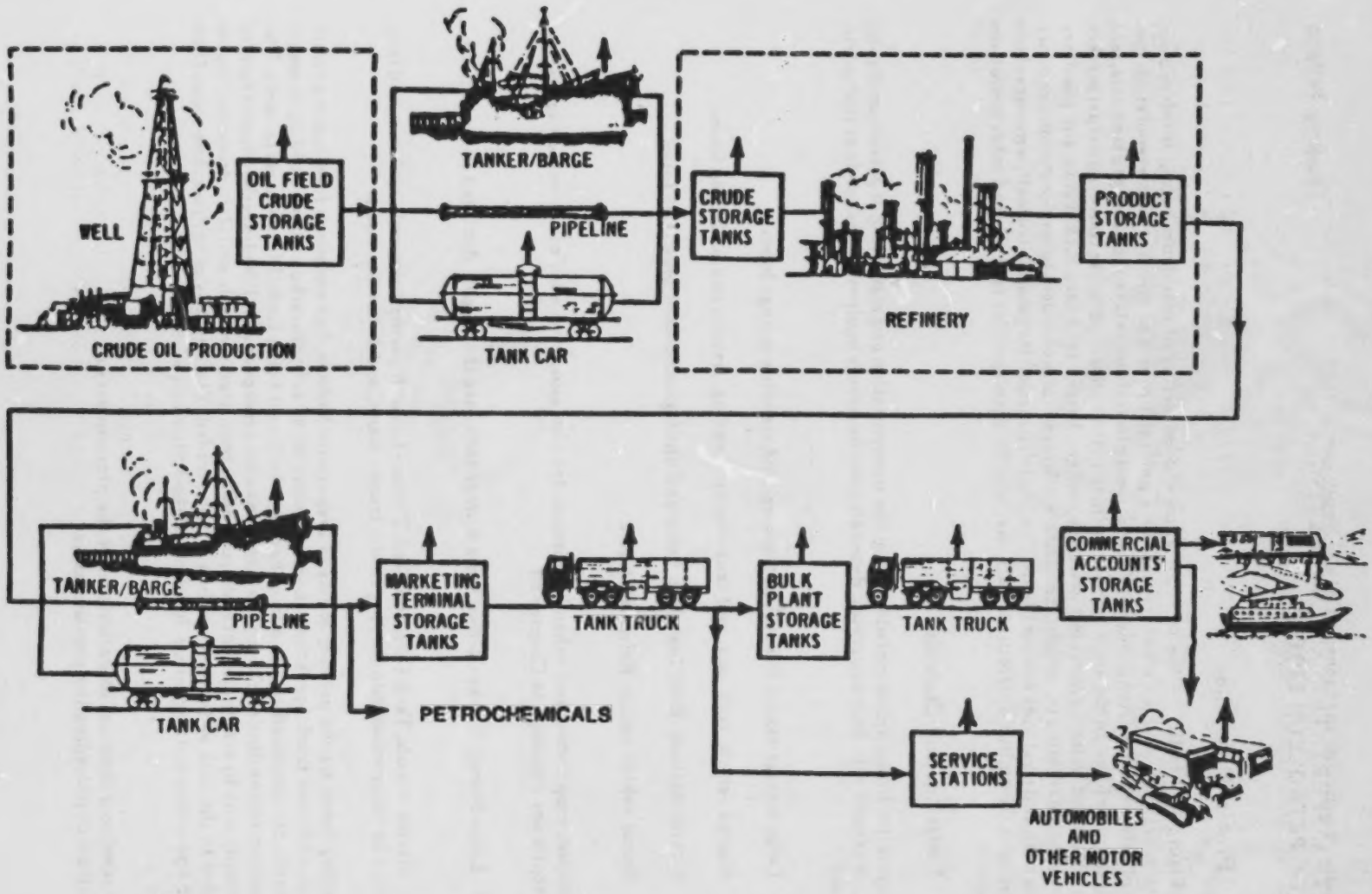

Figure 4.4-1. Flowsheet of petroleum production, refining, and distribution systems. (Sources of organic evaporative emissions are indicated by vertical arrows.)

- Operations during the transport of the empty carrier to the loading terminal.
- Method of loading the new cargo.
- Physical and chemical characteristics of the new cargo.

The principal methods of loading cargo carriers are presented in Figures 4.4-2, 4.4-3, and 4.4-4. In the splash loading method, the fill pipe dispensing the cargo is only partially lowered into the cargo tank. Significant turbulence and vapor-liquid contacting occurs during the splash loading operation, resulting in high levels of vapor generation and loss. If the turbulence is high enough, liquid droplets will be entrained in the vented vapors.

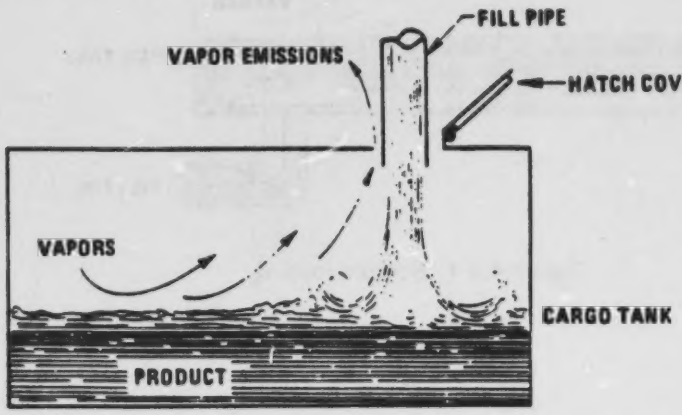

Figure 4.4-2. Splash loading method.

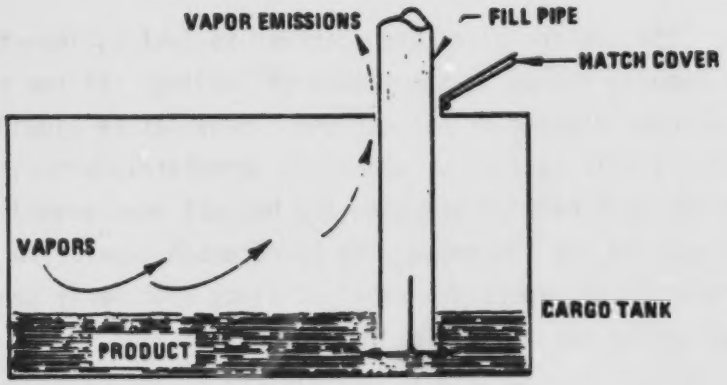

Figure 4.4-3. Submerged fill pipe.

A second method of loading is submerged loading. The two types of submerged loading are the submerged fill pipe method and the bottom loading method. In the submerged fill pipe method, the fill pipe descends almost to the bottom of the cargo tank. In the bottom loading method, the fill pipe enters the cargo tank from the bottom. During the major portion of both forms of submerged loading

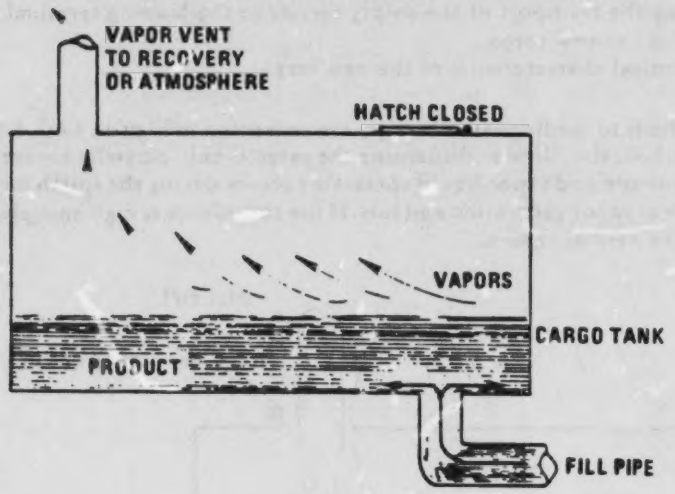

Figure 4.4-4. Bottom loading.

methods, the fill pipe opening is positioned below the liquid level. The submerged loading method significantly reduces liquid turbulence and vapor-liquid contacting, thereby resulting in much lower hydrocarbon losses than encountered during splash loading methods.

The history of a cargo carrier is just as important a factor in loading losses as the method of loading. If the carrier has just been cleaned or has carried a nonvolatile liquid such as fuel oil, it will be full of clean air immediately prior to loading. If it has just carried gasoline and has not been vented, the carrier will be full of air saturated with hydrocarbon vapor. In the latter case, the residual vapors are expelled along with newly generated vapors during the subsequent loading operation.

Some cargo carriers are designated to transport only one product. In this situation, tanks are not cleaned between trips and so return for loading containing air fully or partially saturated with vapor. The extent of this situation differs for marine vessels, tank cars, large and small tank trucks. It also varies with ownership of the carrier, petroleum liquid being transported, geographic location, season of the year, and control measure employed.

Gasoline tank trucks may be in "dedicated balance service," where the truck picks up the vapors displaced during unloading operations and transports them in the empty tank back to the loading terminal. Figure 4.4-5 shows a tank truck in dedicated vapor balance service unloading gasoline to an underground service station tank and filling up with displaced gasoline vapors to be returned to the truck loading terminal. The vapors in an empty gasoline tank truck in dedicated balance service are normally saturated with hydrocarbons. Dedicated balance service is not usually practiced with marine vessels.

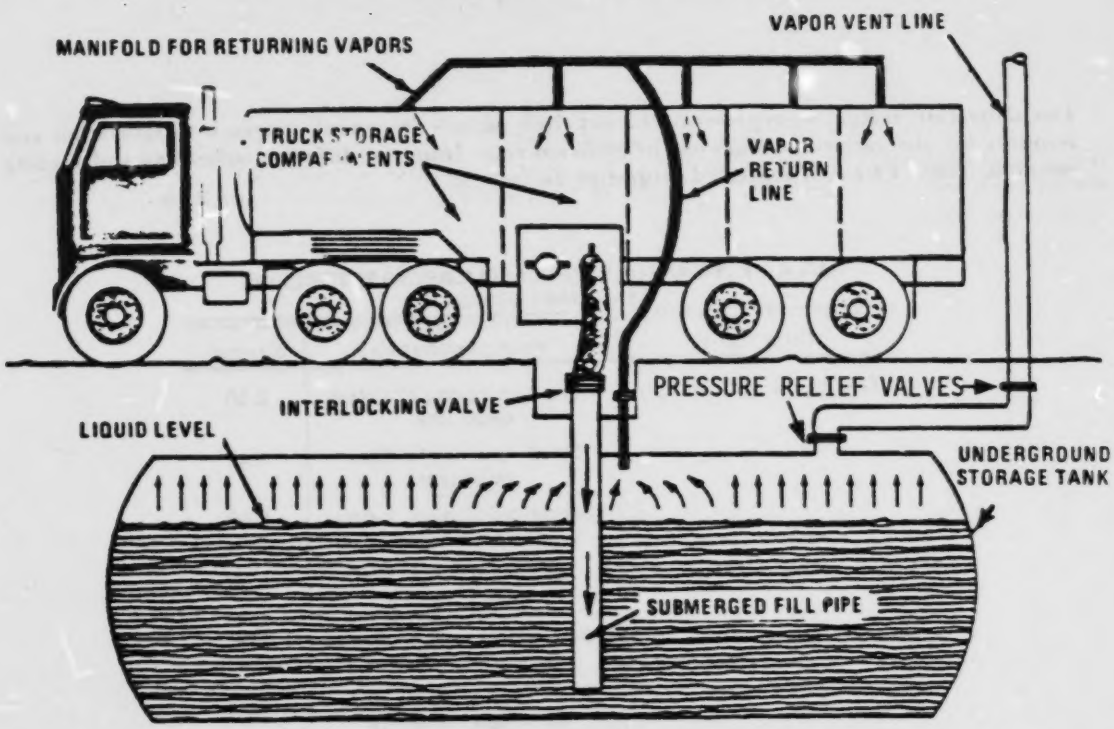

Figure 4.4-5. Tanktruck unloading into an underground service station storage tank. Tanktruck is practicing "vapor balance" form of vapor control.

Emissions from loading hydrocarbon liquid can be estimated (within 30 percent) using the following expression:

$$L_L = 12.46 \frac{SPM}{T} \quad (1)$$

where: L_L = Loading loss, lb/10^3 gal of liquid loaded.

M = Molecular weight of vapors, lb/lb-mole (see Table 4.3-1).

P = True vapor pressure of liquid loading, psia (see Figures 4.3-8 and 4.3-9, and Table 4.3-1).

T = Bulk temperature of liquid loaded, °R.

S = A saturation factor (see Table 4.4-1).

The saturation factor (S) represents the expelled vapor's fractional approach to saturation and accounts for the variations observed in emission rates from the different unloading and loading methods. Table 4.4-1 lists suggested saturation factors (S).

Table 4.4-1. S FACTORS FOR CALCULATING PETROLEUM LOADING LOSSES

Cargo carrier	Mode of operation	S factor
Tank trucks and tank cars	Submerged loading of a clean cargo tank	0.50
	Splash loading of a clean cargo tank	1.45
	Submerged loading: normal dedicated service	0.60
	Splash loading: normal dedicated service	1.45
	Submerged loading: dedicated, vapor balance service	1.00
	Splash loading: dedicated, vapor balance service	1.00
Marine vessels[a]	Submerged loading: ships	0.2
	Submerged loading: barges	0.5

[a]To be used for products other than gasoline; use factors from Table 4.4-2 for marine loading of gasoline.

Ballasting operations are a major source of hydrocarbon emissions associated with unloading petroleum liquids at marine terminals. It is common practice for large tankers to fill several cargo tanks with water after unloading their cargo. This water, termed ballast, improves the stability of the empty tanker on rough seas during the subsequent return voyage. Ballasting emissions occur as hydrocarbon-laden air in the empty cargo tank is displaced to the atmosphere by ballast water being pumped into the empty cargo tank. Although ballasting practices vary quite a bit, individual cargo tanks are ballasted about 80 percent, and the total vessel is ballasted approximately 40 percent of capacity. Ballasting emissions from gasoline and crude oil tankers are approximately 0.8 and 0.6 lb/10^3 gal, respectively, based on total tanker capacity. These estimates are for motor gasolines and medium volatility crudes (RVP≈5 psia).[2] Upon arrival in port, this ballast water is pumped from the cargo tanks before loading the new cargo. The ballasting of cargo tanks reduces the quantity of vapor returning in the empty tanker, thereby reducing the quantity of vapors emitted during subsequent tanker loading operations.

Recent studies on gasoline loading losses from ships and barges have led to the development of more accurate emission factors for these specific loading operations. These factors are presented in Table 4.4-2 and should be used instead of Equation (1) for gasoline loading operations at marine terminals.[2]

Table 4.4-2. HYDROCARBON EMISSION FACTORS FOR GASOLINE LOADING OPERATIONS

Vessel tank condition	Hydrocarbon emission factors					
	Ships		Ocean barges		Barges	
	Range	Average	Range	Average	Range	Average
Cleaned and vapor free						
lb/10^3 gal transferred	0 to 2.3	1.0	0 to 3	1.3	a	1.2
kg/10^3 liter transferred	0 to 0.28	0.12	0 to 0.36	0.16		0.14
Ballasted						
lb/10^3 gal transferred	0.4 to 3	1.6	0.5 to 3	2.1	b	b
kg/10^3 liter transferred	0.05 to 0.36	0.19	0.06 to 0.36	0.25		
Uncleaned - dedicated service						
lb/10^3 gal transferred	0.4 to 4	2.4	0.5 to 5	3.3	1.4 to 9	4.0
kg/10^3 liter transferred	0.05 to 0.48	0.29	0.06 to 0.60	0.40	0.17 to 1.08	0.48
Average cargo tank condition						
lb/10^3 gal transferred	a	1.4	a	a	a	4.0
kg/10^3 liter transferred		0.17				0.48

[a] These values are not available.

[b] Barges are not normally ballasted.

Sample Calculation - Loading losses from a gasoline tank truck in dedicated balance service and practicing vapor recovery would be calculated as follows using Equation (1).

Design basis:

Tank truck volume is 8000 gallons
Gasoline RVP is 9 psia
Dispensing temperature is 80°F
Vapor recovery efficiency is 95%

Loading loss equation:

$$L_L = 12.46 \frac{SPM}{T}\left(1 - \frac{eff}{100}\right)$$

where: S = Saturation factor (see Table 4.4-1) = 1.0
P = True vapor pressure of gasoline (see Figure 4.3-8) = 6.6 psia
M = Molecular weight of gasoline vapors (see Table 4.3-1) = 66
T = Temperature of gasoline = 540°R
eff = The control efficiency = 95%

$$L_L = 12.46 \frac{(1.0)(6.6)(66)}{540}\left(1 - \frac{95}{100}\right)$$

$$= 0.50 \text{ lb}/10^3 \text{ gal}$$

Total loading losses are

$(0.50 \text{ lb}/10^3 \text{ gal})(8.0 \times 10^3 \text{ gal}) = 4.0$ lb of hydrocarbon

Control measures for reducing loading emissions include the application of alternate loading methods producing lower emissions and the application of vapor recovery equipment. Vapor recovery equipment captures hydrocarbon vapors displaced during loading and ballasting operations and recovers the hydrocarbon vapors by the use of refrigeration, absorption, adsorption, and/or compression. Figure 4.4-6 demonstrates the recovery of gasoline vapors from tank trucks during loading operation at bulk terminals. Control efficiencies range from 90 to 98 percent depending on the nature of the vapors and the type of recovery equipment employed.[4]

Emissions from controlled loading operations can be calculated by multiplying the uncontrolled emission rate calculated in Equations (1) and (2) by the control efficiency term:

$$\left[1 - \frac{\text{efficiency}}{100}\right]$$

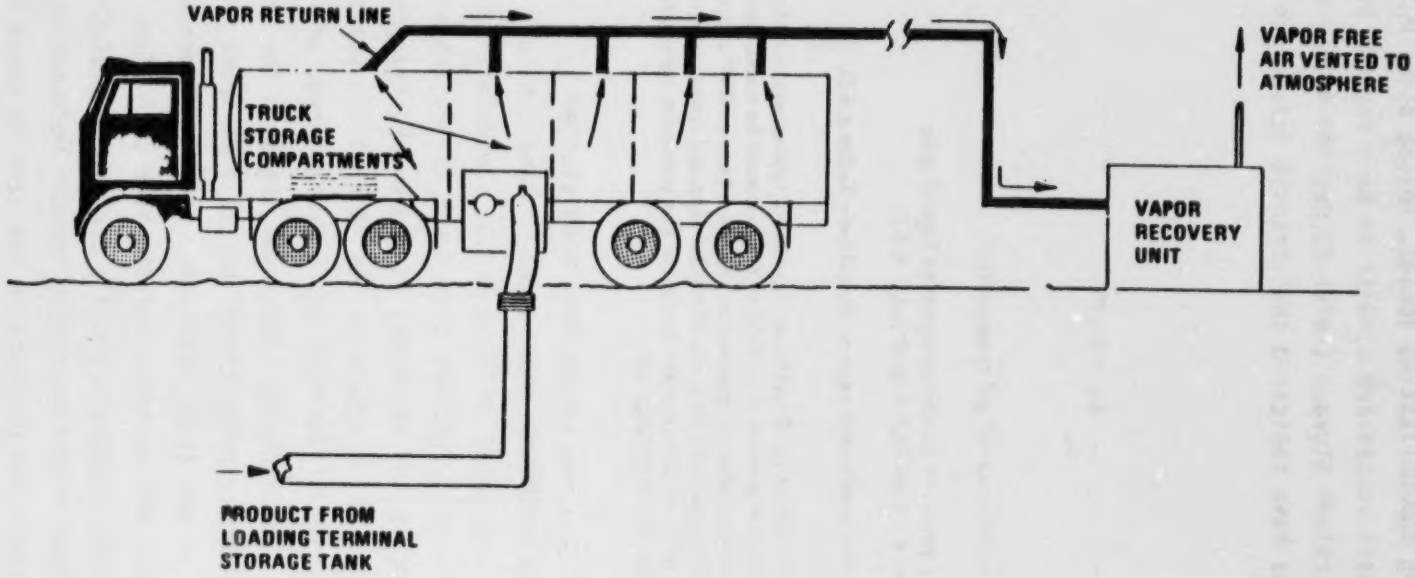

Figure 4.4-6. Tanktruck loading with vapor recovery.

In addition to loading and ballasting losses, losses occur while the cargo is in transit. Transit losses are similar in many ways to breathing losses associated with petroleum storage (refer to section 4.3). Experimental tests on tankers and barges have indicated that transit losses can be calculated using Equation (2):[3]

$$L_T = 0.1\,PW \qquad (2)$$

where: L_T = Transit loss, lb/week-10^3 gal transported.

P = True vapor pressure of the transported liquid, psia (see Figures 4.3-8 and 4.3-9, and Table 4.3-1).

W = Density of the condensed vapors, lb/gal (see Table 4.3-1).

In the absence of specific inputs for Equations (1) and (2), typical evaporative hydrocarbon emissions from loading operations are presented in Table 4.4-3. It should be noted that, although the crude oil used to calculate the emission values presented in Table 4.4-3 has an RVP of 5, the RVP of crude oils can range over two orders of magnitude. In areas where loading and transportation sources are major factors affecting the air quality it is advisable to obtain the necessary parameters and to calculate emission estimates from Equations (1) and (2).

Emissions from gasoline trucks have been studied by a combination of theoretical and experimental techniques,[7,8] and typical emission values are presented in Table 4.4-3. Emissions depend upon the extent of venting from the tank truck during transit, which in turn depends on the tightness of the truck, the pressure relief valve settings, the pressure in the tank at the start of the trip, the vapor pressure of the fuel being transported, and the degree of saturation (with fuel vapor) of the vapor space in the tank. The emissions are <u>not</u> directly proportional to the time spent in transit. As the leakage rate of the truck increases, emissions increase up to a point and then level off as other factors take over. Tank trucks in dedicated vapor balance service typically contain saturated vapors, and this leads to lower emissions during transit because no additional fuel evaporates to raise the pressure in the tank to cause venting. Table 4.4-3 lists "typical" values for emissions and "extreme" values which could occur in the unlikely event that all determining factors combined to cause maximum emissions.

Table 4.4-3. HYDROCARBON EMISSION FACTORS FOR PETROLEUM LIQUID TRANSPORTATION AND MARKETING SOURCES

Emission source	Product emission factors[a]					
	Gasoline[b]	Crude oil[c]	Jet naphtha (JP-4)	Jet kerosene	Distillate oil No. 2	Residual oil No. 6
Tank cars/trucks						
Submerged loading-normal service						
lb/10^3 gal transferred	5	3	1.5	0.02	0.01	0.0001
kg/10^3 liters transferred	0.6	0.4	0.18	0.002	0.001	0.00001
Splash loading-normal service						
lb/10^3 gal transferred	12	7	4	0.04	0.03	0.0003
kg/10^3 liters transferred	1.4	0.8	0.5	0.005	0.004	0.00004
Submerged loading-balance service						
lb/10^3 gal transferred	8	5	2.5	d	d	d
kg/10^3 liters transferred	1.0	0.6	0.3			
Splash loading-balance service						
lb/10^3 gal transferred	8	5	2.5	d	d	d
kg/10^3 liters transferred	1.0	0.6	0.3			
Transit-loaded with fuel						
lb/10^3 gas transferred	0-0.01 typical	e	e	e	e	e
	0-0.08 extreme	e	e	e	e	e
kg/10^3 liters transferred	0-0.001 typical	e	e	e	e	e
	0-0.009 extreme	e	e	e	e	e
Transit-return with vapor						
lb/10^3 gal transferred	0-0.11 typical	e	e	e	e	e
	0-0.37 extreme	e	e	e	e	e
kg/10^3 liters transferred	0-0.013 typical	e	e	e	e	e
	0-0.044 extreme	e	e	e	e	e
Marine vessels						
Loading tankers						
lb/10^3 gal transferred	f	0.07	0.05	0.005	0.005	0.00004
kg/10^3 liters transferred		0.08	0.06	0.0006	0.0006	5×10^{-6}
Loading Barges						
lb/10^3 gal transferred	f	1.7	1.2	0.0013	0.012	0.00009
kg/10^3 liters transferred	f	0.20	0.14	0.0016	0.0014	1.1×10^{-5}
Tanker ballasting						
lb/10^3 gal cargo capacity	0.8	0.6	e	e	e	e
kg/10^3 liters cargo capacity	0.10	0.07				
Transit						
lb/week - 10^3 gal transported	3	1	0.7	0.005	0.005	3×10^{-5}
kg/week - 10^3 liters transported	0.4	0.1	0.08	0.0006	0.0006	4×10^{-6}

a Emission factors are calculated for dispensed fuel temperature of 60°F.
b The example gasoline has an RVP of 10 psia.
c The example crude oil has an RVP of 5 psia.
d Not normally used.
e Not available.
f See Table 4.4-2 for these emission factors.

4.4.2.3 Service Stations - Another major source of evaporative hydrocarbon emissions is the filling of underground gasoline storage tanks at service stations. Normally, gasoline is delivered to service stations in large (8000 gallon) tank trucks. Emissions are generated when hydrocarbon vapors in the underground storage tank are displaced to the atmosphere by the gasoline being loaded into the tank. As with other loading losses, the quantity of the service station tank loading loss depends on several variables including the size and length of the fill pipe, the method of filling, the tank configuration, and the gasoline temperature, vapor pressure, and composition. An average hydrocarbon emission rate for submerged filling is 7.3 lb/10^3 gallons of transferred gasoline, and the rate for splash filling is 11.5 lb/10^3 gallons of transferred gasoline (Table 4.4-4).[4]

Emissions from underground tank filling operations at service stations can be reduced by the use of the vapor balance system (Figure 4.4-5). The vapor balance system employs a vapor return hose which returns gasoline vapors displaced from the underground tank to the tank truck storage compartments being emptied. The control efficiency of the balance system ranges from 93 to 100 percent. Hydrocarbon emissions from underground tank filling operations at a service station employing the vapor balance system and submerged filling are not expected to exceed 0.3 lb/10^3 gallons of transferred gasoline.

A second source of hydrocarbon emissions from service stations is underground tank breathing. Breathing losses occur daily and are attributed to temperature changes, barometric pressure changes, and gasoline evaporation. The type of service station operation also has a large impact on breathing losses. An average breathing emission rate is 1 lb/10^3 gallons throughput.[5]

4.4.2.4 Motor Vehicle Refueling - An additional source of evaporative hydrocarbon emissions at service stations is vehicle refueling operations. Vehicle refueling emissions are attributable to vapors displaced from the automobile tank by dispensed gasoline and to spillage. The quantity of displaced vapors is dependent on gasoline temperature, auto tank temperature, gasoline RVP, and dispensing rates. Although several correlations have been developed to estimate losses due to displaced vapors, significant controversy exists concerning these correlations. It is estimated that the hydrocarbon emissions due to vapors displaced during vehicle refueling average 9 lb/10^3 gallons of dispensed gasoline.[4,5]

The quantity of spillage loss is a function of the type of service station, vehicle tank configuration, operator technique, and operation discomfort indices. An overall average spillage loss is 0.7 lb/10^3 gallons of dispensed gasoline.[4]

Control methods for vehicle refueling emissions are based on conveying the vapors displaced from the vehicle fuel tank to the underground storage tank vapor space through the use of a special hose and nozzle (Figure 4.4-7). In the "balance" vapor control system, the vapors are conveyed by natural pressure differentials established during refueling. In "vacuum assist" vapor control systems, the conveyance of vapors from the auto fuel tank to the underground fuel tank is assisted by a vacuum pump. The overall control efficiency of vapor control systems for vehicle refueling emissions is estimated to be 88 to 92 percent.[4]

Table 4.4-4. HYDROCARBON EMISSIONS FROM GASOLINE SERVICE STATION OPERATIONS

Emission source	Emission rate	
	lb/10^3 gal throughput	kg/10^3 liters throughput
Filling underground tank		
Submerged filling	7.3	0.88
Splash filling	11.5	1.38
Balanced submerged filling	0.3	0.04
Underground tank breathing and emptying[a]	1	0.12
Vehicle refueling operations		
Displacement losses (uncontrolled)	9	1.08
Displacement losses (controlled)	0.9	0.11
Spillage	0.7	0.084

a Emissions include any vapor loss from the underground tank to the gas pump.

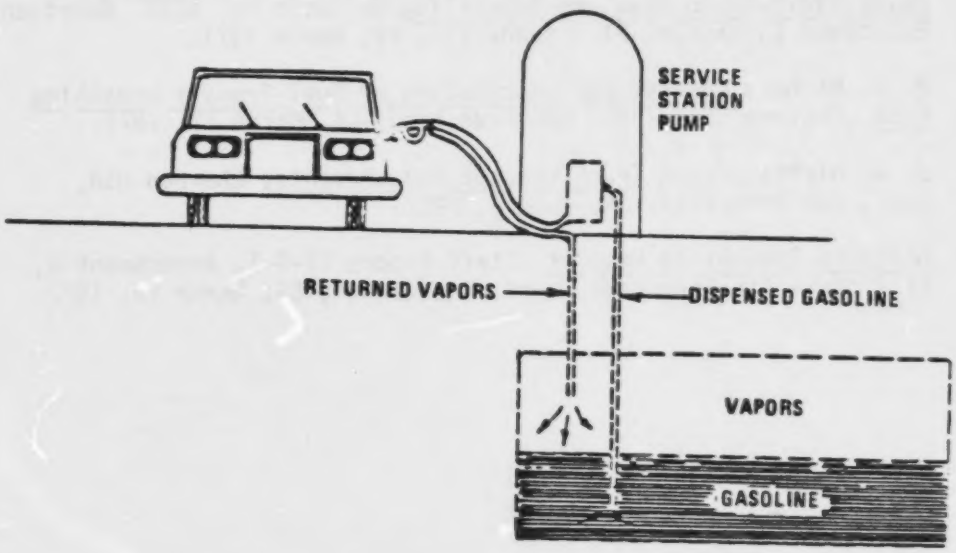

Figure 4.4-7. Automobile refueling vapor-recovery system.

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4.5 CUTBACK ASPHALT, EMULSIFIED ASPHALT AND ASPHALT CEMENT — Tom Lahre

4.5.1 General [1-3]

Asphalt surfaces and pavements are composed of compacted aggregate and an asphalt binder. Aggregate materials are produced from rock quarries as manufactured stone or are obtained from natural gravel or soil deposits. Metal ore refining processes produce artificial aggregates as a by-product. In asphalt, the aggregate performs three functions. It transmits the load from the surface to the base course, takes the abrasive wear of traffic, and provides a nonskid surface. The asphalt binder holds the aggregate together, preventing displacement and loss of aggregate and providing a waterproof cover for the base.

Asphalt binders take the form of asphalt cement (the residue of the distillation of crude oils) and liquified asphalts. To be used for pavement, asphalt cement, which is semisolid, must be heated prior to mixing with aggregate. The resulting hot mix asphalt concrete is generally applied in thicknesses of from two to six inches. Liquified asphalts are: (1) asphalt cutbacks (asphalt cement thinned or "cutback" with volatile petroleum distillates such as naptha, kerosene, etc.) and (2) asphalt emulsions (nonflammable liquids produced by combining asphalt and water with an emulsifying agent, such as soap). Liquified asphalts are used in tack and seal operations, in priming roadbeds for hot mix application, and for paving operations up to several inches thick.

Cutback asphalts fall into three broad categories: rapid cure (RC), medium cure (MC), and slow cure (SC) road oils. SC, MC and RC cutbacks are prepared by blending asphalt cement with heavy residual oils, kerosene-type solvents, or naptha and gasoline solvents, respectively. Depending on the viscosity desired, the proportions of solvent added generally range from 25 to 45 percent by volume.

Emulsified asphalts are of two basic types. One type relies on water evaporation to cure. The other type (cationic emulsions) relies on ionic bonding of the emulsion and the aggregate surface. Emulsified asphalt can substitute for cutback in almost any application. Emulsified asphalts are gaining in popularity because of the energy and environmental problems associated with the use of cutback asphalts.

4.5.2 Emissions [1,2]

The primary pollutants of concern from asphalts and asphalt paving operations are volatile organic compounds (VOC). Of the three types of asphalts, the major source of VOC is cutback. Only minor amounts of VOC are emitted from emulsified asphalts and asphalt cement.

VOC emissions from cutback asphalts result from the evaporation of the petroleum distillate solvent, or diluent, used to liquify the asphalt cement. Emissions occur at both the job site and the mixing plant. At the job site, VOCs are emitted from the equipment used to apply the asphaltic product and from the road surface. At the mixing plant, VOCs are released during mixing and stockpiling. The largest source of emissions, however, is the road surface itself.

For any given amount of cutback asphalt, total emissions are believed to be the same, regardless of stockpiling, mixing and application times. The two major variables affecting both the quantity of VOC emitted and the time over which emissions occur are the type and the quantity of petroleum distillate used as a diluent. As an approximation, long term emissions from cutback asphalts can be estimated by assuming that 95 percent of the diluent evaporates from rapid cure (RC) cutback asphalts, 70 percent from medium cure (MC) cutbacks, and about 25 percent from slow cure (SC) asphalts, by weight percent. Some of the diluent appears to be retained permanently

in the road surface after application. Limited test data suggest that, from rapid cure (RC) asphalt, 75 percent of the total diluent loss occurs on the first day after application, 90 percent occurs within the first month, and 95 percent in three to four months. Evaporation takes place more slowly from medium cure (MC) asphalts, with roughly 20 percent of the diluent being emitted during the first day, 50 percent during the first week, and 70 percent after three to four months. No measured data are available for slow cure (SC) asphalts, although the quantity emitted is believed to be considerably less than with either rapid or medium cure asphalts, and the time during which emissions take place is expected to be considerably longer (Figure 4.5-1). An example calculation for determing VOC emissions from cutback asphalts is given below:

Example: Local records indicate that 10,000 kg of RC cutback asphalt (containing 45 percent diluent, by volume) was applied in a given area during the year. Calculate the mass of VOC emitted during the year from this application.

To determine VOC emissions, the volume of diluent present in the cutback asphalt must first be determined. Because the density of naptha (0.7 kg/l) differs from that of asphalt cement (1.1 kg/l), the following equations should be solved to determine the volume of diluent (x) and the volume of asphalt cement (y) in the cutback asphalt:

$$10{,}000 \text{ kg cutback asphalt} = (x \text{ liter, diluent})\left(0.7 \frac{\text{kg}}{\text{liter}}\right)$$

$$+ (y \text{ liter, asphalt cement}).\left(1.1 \frac{\text{kg}}{\text{liter}}\right)$$

and

$$\frac{x}{y} = \frac{0.45}{0.55}, \begin{matrix} (\%, \text{ by volume, of diluent}) \\ (\%, \text{ by volume, of asphalt cement}) \end{matrix}$$

From these equations, the volume of diluent present in the cutback asphalt is determined to be about 4900 liters, or about 3400 kg. Assuming that 95 percent of this is evaporative VOC, emissions are then: 3400 kg x 0.95 = 3200 kg (i.e., 32%, by weight, of the cutback asphalt eventually evaporates)

These equations can be used for medium cure and slow cure asphalts by assuming typical diluent densities of 0.8 and 0.9 kg/liter, respectively. Of course, if actual density values are known from local records, they should be used in the above equations rather than typical values. Also, if different diluent contents are used, they should also be reflected in the above calculations. If actual diluent contents are not known, a typical value of 35 percent may be assumed for inventory purposes.

In lieu of solving the equations in the above example, Table 4.5-1 may be used to estimate long term emissions from cutback asphalts. Table 4.5-1 directly yields long term emissions as a function of the volume of diluent added to the cutback and of the density of the diluents and asphalt cement used in the cutback asphalt. If short term emissions are to be estimated, Figure 4.5-1 should be used in conjunction with Table 4.5-1.

No control devices are employed to reduce evaporative emissions from cutback asphalts. Asphalt emulsions are typically utilized in place of cutback asphalts to eliminate VOC emissions.

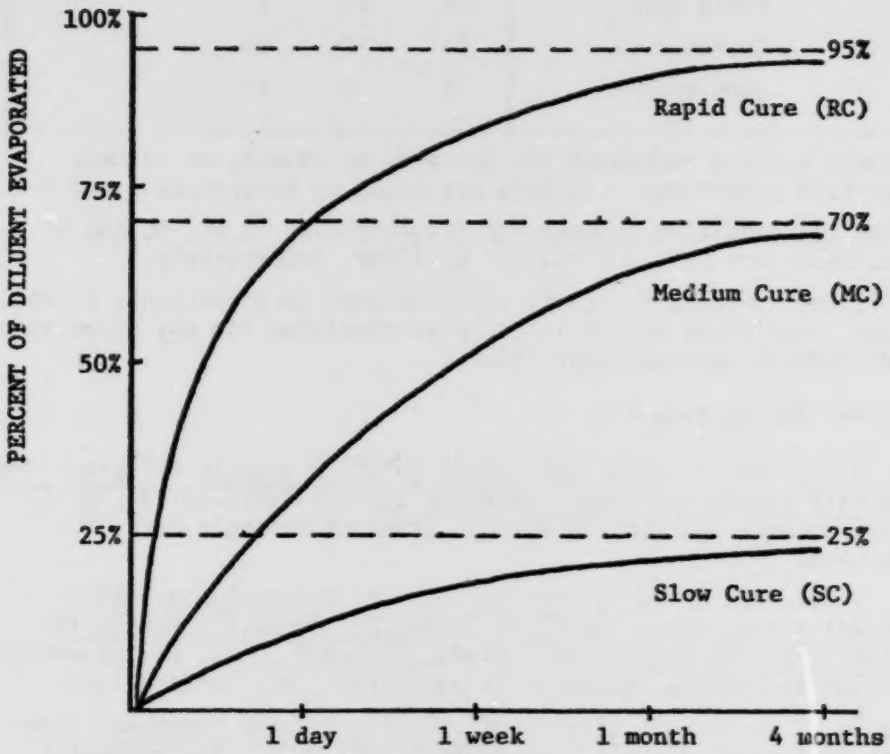

Figure 4.5-1. Percent of diluent evaporated from cutback asphalt over time.

TABLE 4.5-1. EVAPORATIVE VOC EMISSIONS FROM CUTBACK ASPHALTS AS A FUNCTION OF DILUENT CONTENT AND CUTBACK ASPHALT TYPE[a]

(EMISSION FACTOR RATING: C)

Type of Cutback[b]	Percent, by Volume, of Diluent in Cutback[c]		
	25	35	45
Rapid cure	17	24	32
Medium cure	14	20	26
Slow cure	5	8	10

[a]These numbers represent the percent, by weight, of cutback asphalt evaporated. Factors are based on References 1 and 2.

[b]Typical densities assumed for diluents used in RC, MC and SC cutbacks are 0.7, 0.8 and 0.9 kg/liter, respectively.

[c]Diluent contents typically range between 25-45 percent, by volume. Emissions may be linearly interpolated for any given type of cutback between these values.

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4.6 SOLVENT DEGREASING

Audrey McBath

4.6.1 Process Description [1,2]

Solvent degreasing (or solvent cleaning) is the physical process of using organic solvents to remove grease, fats, oils, wax or soil from various metal, glass or plastic items. The types of equipment used in this method are categorized as cold cleaners, open top vapor degreasers or conveyorized degreasers. Nonaqueous solvents such as petroleum distillates, chlorinated hydrocarbons, ketones and alcohol are used. Solvent selection is based on the solubility of the substance to be removed and the toxicity, flammability, flash point, evaporation rate, boiling point, cost and several other properties of the solvent.

The metal working industry is the major user of solvent degreasing, i.e., automotive, electronics, plumbing, aircraft, refrigeration and business machine industries. Solvent cleaning is also used in industries such as printing, chemicals, plastics, rubber, textiles, glass, paper and electric power. Most repair stations for transportation vehicles and electric tools utilize solvent cleaning at least part of the time. Many industries use water based alkaline wash systems for degreasing, and since these systems emit no solvent vapors to the atmosphere, they are not included in this discussion.

4.6.1.1 Cold Cleaners - The two basic types of cold cleaners are maintenance and manufacturing. Cold cleaners are batch loaded, non-boiling solvent degreasers, usually the simplest and least expensive method of metal cleaning. Maintenance cold cleaners are more numerous and smaller, generally using petroleum solvents such as mineral spirits (petroleum distillates and Stoddard solvents). Manufacturing cold cleaners use a wide variety of solvents, which perform higher quality cleaning, are more specialized, and have twice the average emission rate of maintenance cold cleaners. Some cold cleaners can serve both purposes.

Cold cleaner operations include spraying, brushing, flushing and immersion. In a typical maintenance cleaner (Figure 4.6-1), dirty parts are cleaned manually by spraying and then soaking in the tank. After cleaning, the parts are either suspended over the tank to drain or are placed on an external rack that routes the drained solvent back into the cleaner. The cover is intended to be closed whenever parts are not being handled in the cleaner. Manufacturing cold cleaners vary widely in design, but there are two basic tank designs: the simple spray sink and the dip tank. Of these, the dip tank provides more thorough cleaning through soaking and often improves cleaning efficiency by agitation.

4.6.1.2 Open Top Vapor Systems - Open top vapor degreasers are batch loaded boiling degreasers that clean using condensation of hot solvent vapor on colder metal parts. Vapor degreasing uses halogenated solvents (usually perchloroethylene, trichloroethylene, or 1,1,1-trichloroethane), because they are not flammable, and their vapors are much heavier than air.

A typical vapor degreaser (Figure 4.6-1) is a sump containing a heater that boils the solvent to generate vapors. The upper level of these pure vapors is controlled by condenser coils and/or a water jacket encircling the device. A "freeboard" extends above the top of the vapor zone to minimize vapor escape. Parts to be cleaned are immersed in the vapor zone, and condensation continues until they are heated to the vapor temperature. Residual liquid solvent on the parts rapidly evaporates as they are slowly removed from the vapor zone. Cleaning action is often increased by spraying the parts with solvent below the vapor level or by immersing them in the liquid solvent bath. Nearly all vapor degreasers are equipped with a water separator which allows the solvent to flow back into the degreaser. Many also have lip mounted exhaust systems which capture solvent

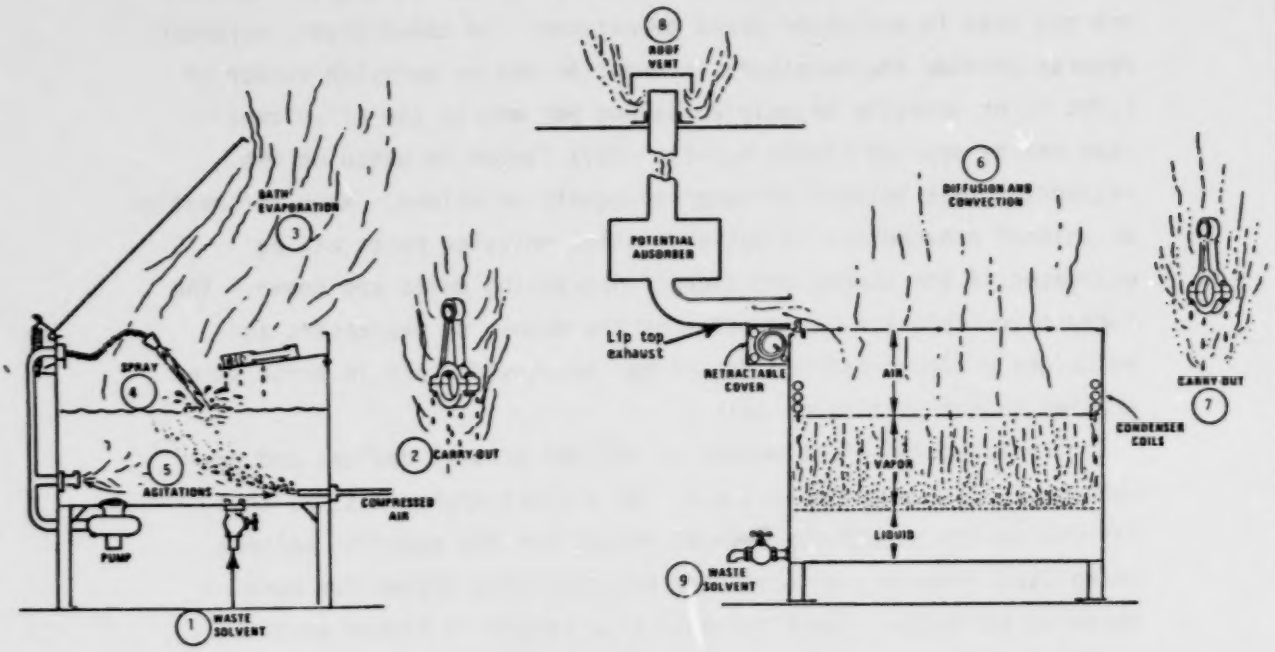

Figure 4.6-1. Degreaser emission points

Emission rates are usually estimated from solvent consumption data for the particular degreasing operation under consideration. Solvents are often purchased specifically for use in degreasing and are not used in any other plant operations. In these cases, purchase records provide the necessary information and an emission factor of 1,000 kg of volatile organic emissions per metric ton of solvent used can be applied (Table 4.6-1). This factor is based on the assumption that solvent consumption equals emissions. When information on solvent consumption is not available, emission rates can be estimated if the number and type of degreasing units are known. The factors in Table 4.6-1 are based on the number of degreasers and emissions produced nationwide and may be considerably in error when applied to one particular unit.

The expected effectiveness of various control devices and procedures is listed in Table 4.6-2. As a first approximation, this efficiency can be applied without regard for the specific solvent being used. However, efficiencies are generally higher for more volatile solvents. These solvents also result in higher emission rates than those computed from the "average" factors listed in Table 4.6-1.

Table 4.6-1. SOLVENT LOSS EMISSION FACTORS FOR DEGREASING OPERATIONS.
(EMISSION FACTOR RATING: C)

Type of degreasing	Activity measure	Uncontrolled organic emission factor[a]	
All[b]	Solvent consumed	2,000 lb/ton	1,000 kg/MT
Cold cleaner			
Entire unit[c]	Units in operation	0.33 tons/yr·unit	0.30 MT/yr·unit
Waste solvent loss		0.18 tons/yr·unit	0.165 MT/yr·unit
Solvent carryout		0.08 tons/yr·unit	0.075 MT/yr·unit
Bath and spray evaporation		0.07 tons/yr·unit	0.060 MT/yr·unit
Entire unit	Surface area and duty cycle[d]	0.08 lb/hr. ft^2	0.4 kg/hr. m^2
Open top vapor			
Entire unit	Units in operation	10.5 tons/yr·unit	9.5 MT/yr·unit
Entire unit	Surface area and duty cycle[e]	0.15 lb/hr·ft^2	0.7 kg/hr·m^2
Conveyorized, vapor			
Entire unit	Units in operation	26 tons/yr·unit	24 MT/yr·unit
Conveyorized, nonboiling			
Entire unit	Units in operation	52 tons/yr·unit	47 MT/yr·unit

[a]100 percent nonmethane hydrocarbons or volatile organic compounds.

[b]Solvent consumption data will provide much more accurate emission estimates than any of the other factors presented.

[c]Emissions would generally be higher for manufacturing units and lower for maintenance units.

[d]For trichloroethane degreaser. From Reference 3, Appendix C-6.

[e]For trichloroethane degreaser. Does not include waste solvent losses.

4.6.1.3 Conveyorized Degreasers - Conveyorized degreasers may operate with either cold or vaporized solvent, but they merit separate consideration because they are continuously loaded and are almost always hooded or enclosed. About 85 percent are vapor types, and 15 percent are nonboiling.

4.6.2 Emissions and Controls[1,2,3]

Emissions from cold cleaners occur through (1) waste solvent evaporation, (2) solvent carry-out (evaporation from wet parts), (3) solvent bath evaporation, (4) spray evaporation, and (5) agitation (Figure 4.6-1). Waste solvent loss, cold cleaning's greatest emission source, can be minimized through distillation and special incineration plants. Draining cleaned parts for at least 15 seconds reduces carry-out emissions. Bath evaporation can be controlled by regularly using a cover, allowing an adequate freeboard height and avoiding excessive drafts in the workshop. If the solvent used is insoluble in, and heavier than, water, a layer of water about two to four inches thick covering the halogenated solvent can also reduce bath evaporation. This is known as a "water cover". Spraying at low pressure helps to reduce solvent loss from this part of the process. Agitation emissions can be controlled by using a cover, agitating no longer than necessary, and avoiding the use of agitation with low volatility solvents. Emissions of low volatility solvents increase significantly with agitation. However, contrary to what one might expect, agitation causes only a small increase in emissions of high volatility solvents. Solvent type, particularly its volatility at the operating temperature, is the variable which most affects cold cleaner emission rates.

As with cold cleaning, open top vapor degreasing emissions relate heavily to proper operating methods. Most emissions are due to (6) diffusion and convection, which can be minimized by using an

Table 4.6-2. Projected Emission Reduction Factors for Solvent Degreasing[a]

System	Cold Cleaner		Vapor Degreaser		Conveyorized Degreaser	
	A	B	C	D	E	F
Control Devices						
cover or enclosed design	X	X	X	X	X	X
drainage facility	X	X	X			X
water cover, refrigerated chiller, carbon adsorption or high freeboard[b]		X		X		X
solid, fluid spray stream[c]						
safety switches and thermostats				X		X
emission reduction from control devices	13-38	NA[e]	20-40	30-60		40-60
Operating Procedures						
proper use of equipment	X	X	X	X	X	X
use of high volatility solvent		X				
waste solvent reclamation	X	X	X	X	X	X
reduced exhaust ventilation			X	X	X	X
reduced conveyer or entry speed			X	X	X	X
emission reduction from operating procedures	15-45	NA[e]	15-35	20-40	20-30	20-30
Total Emission Reduction (percentage)	28-83[d]	55-69[f]	30-60	45-75	20-30	50-70

[a]Reference 2. Ranges of emission reduction represent poor to excellent compliance.

[b]Only one of these major control devices would be used in any degreasing system. System B could employ any o' them; system D could employ any except water cover; system F could employ any except water cover and high freeboard.

[c]If agitation by spraying is used, the spray should not be a shower type.

[d]A manual or mechanically assisted cover would contribute 6-18% reduction; draining parts 15 seconds within the degreaser, 7-20%; and storing waste solvent in containers, an additional 15-45%.

[e]Breakdown between control equipment and operating procedures is not available.

[f]Percentages represent average compliance.

automated cover, regularly using a manual cover, spraying below the vapor level, optimizing work loads, or using a refrigerated freeboard chiller (for which a carbon adsorption unit would be substituted on larger units). Safety switches and thermostats that prevent emissions during malfunctions and abnormal operation also reduce diffusion and convection from the vaporized solvent. Additional sources are (7) solvent carry-out, (8) exhaust systems and (9) waste solvent evaporation (Figure 4.6-1). Carry-out is directly affected by the size and shape of the workload, racking of parts, and cleaning and drying time. Exhaust emissions can be nearly eliminated by a carbon adsorber that collects the solvent vapors for reuse. Waste solvent evaporation is not so much a problem with vapor degreasers as it is with cold cleaners, because the halogenated solvents used are often distilled and recycled by solvent recovery systems.

Because of their large workload capacity and the fact that they are usually enclosed, conveyorized degreasers emit less solvent per part cleaned than either of the other two types of degreaser. Compared to operating practices, design and adjustment are major factors affecting emissions, the main source of which is carry-out of vapor and liquid solvents.

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5.2 SYNTHETIC AMMONIA

Frank Noonan

5.2.1 General

Anhydrous ammonia is synthesized by reacting hydrogen with nitrogen at a molar ratio of 3:1, then compressing the gas and cooling it to -33°C. Nitrogen is obtained from the air, while hydrogen is obtained from either the catalytic steam reforming of natural gas (methane) or naphtha, or the electrolysis of brine at chlorine plants. In the United States, about 98 percent of the synthetic ammonia is produced by catalytic steam reforming of natural gas.

Seven process steps are required to produce synthetic ammonia by the catalytic steam reforming method (Figure 5.2-1):

Natural gas desulfurization
Primary reforming with steam
Secondary reforming with air
Carbon monoxide shift
Carbon dioxide removal
Methanation
Ammonia synthesis

The first, fourth, fifth and sixth steps are to remove impurities such as sulfur, CO, CO_2 and water from the feedstock, hydrogen and synthesis gas streams. In the second step, hydrogen is manufactured, and in the third step, additional hydrogen is manufactured and nitrogen is introduced into the process. The seventh step produces anhydrous ammonia from the synthetic gas. While all ammonia plants use this basic process, details such as pressures, temperatures and quantities of feedstock will vary from plant to plant.

5.2.2 Emissions

Pollutants from the manufacture of synthetic anhydrous ammonia are emitted from four process steps:

Regeneration of the desulfurization bed
Heating of the primary reformer
Regeneration of carbon dioxide scrubbing solution
Steam stripping of process condensate

More than 95 percent of the ammonia plants in the U. S. use activated carbon fortified with metallic oxide additives for feedstock desulfurization. The desulfurization bed must be regenerated about once every

30 days for a 10 hour period. Vented regeneration steam contains sulfur oxides and/or hydrogen sulfide, depending on the amount of oxygen in the steam. Regeneration also emits hydrocarbons and carbon monoxide. The primary reformer, heated with natural gas or fuel oil, emits the combustion products NO_x, CO, SO_x, HC and particulates.

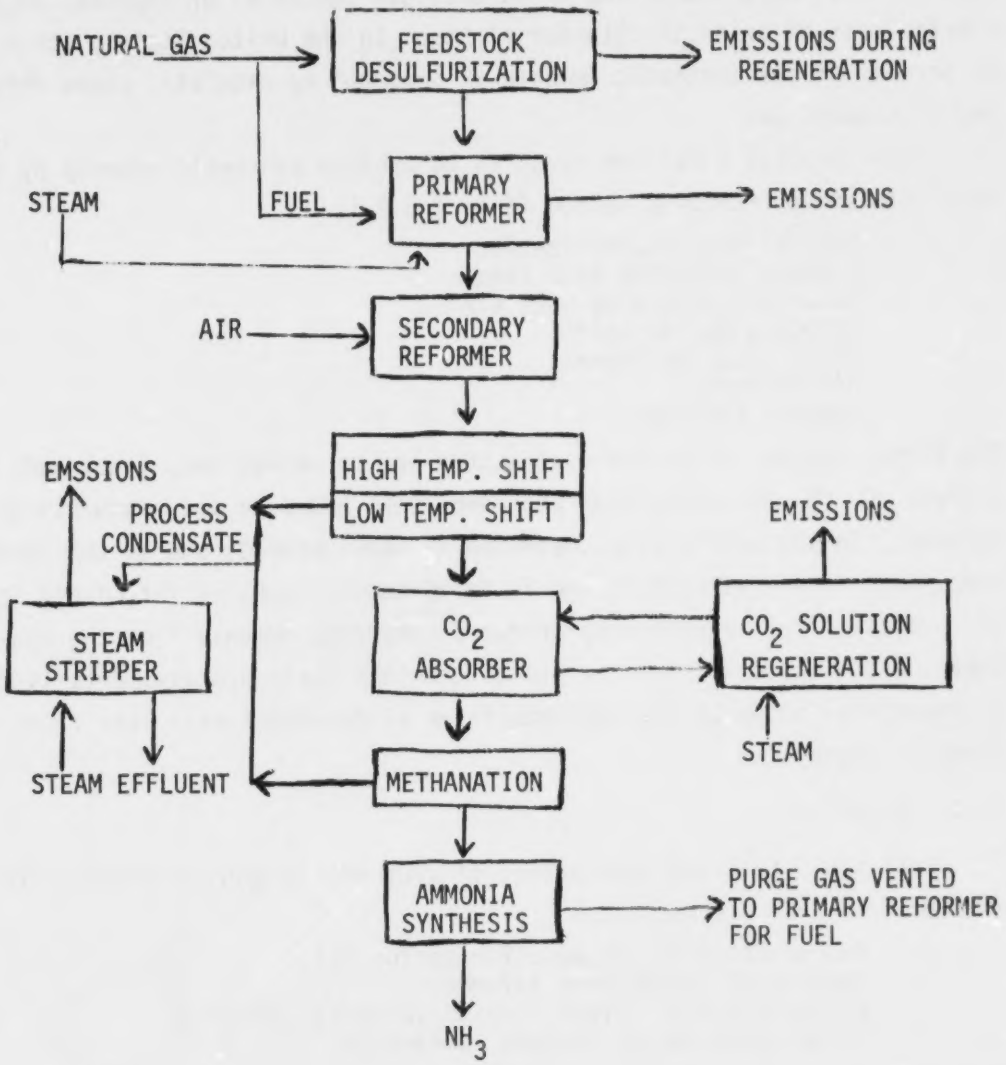

Figure 5.2-1 General process flow diagram of a typical ammonia plant.

Carbon dioxide is removed from the synthesis gas by scrubbing with monoethanolamine or hot potassium carbonate solution. Regeneration of this CO_2 scrubbing solution with steam produces emissions of HC, NH_3, CO, CO_2 and monoethanolamine.

Cooling the synthesis gas after low temperature shift conversion forms a condensate containing quantities of NH_3, CO_2, methanol and trace metals. Condensate steam strippers are used to remove NH_3 and methanol from the water, and steam from this is vented to the atmosphere, emitting NH_3, CO_2 and methanol.

Table 5.2-1 presents emission factors for the typical ammonia plant. Control devices are not used at such plants, so the values in Table 5.2-1 represent uncontrolled emissions.

5.2.3 Controls

Add-on air pollution control devices are not used at synthetic ammonia plants because their emissions are below state standards. Some processes have been modified to reduce emissions and to improve utility of raw materials and energy. Some plants are considering techniques to eliminate emissions from the condensate steam stripper, one such being the injection of the overheads into the reformer stack along with the combustion gases.

Table 5.2-1. UNCONTROLLED EMISSION FACTORS FOR TYPICAL AMMONIA PLANT
(EMISSION FACTOR RATING: A)

Emission Point	Emission Species	lb/ton	kg/MT
Desulfurization[a]	Total sulfur[b,c]	0.019	0.0096
	CO[c]	13.8	6.9
	HC[c]	7.2	3.6
Primary reformer (natural gas)	NO_x	5.8	2.9
	SO_x	0.0048	0.0024
	CO	0.136	0.068
	TSP	0.144	0.072
	HC[d]	0.024	0.012
(fuel oil)	NO_x	5.4	2.7
	SO_x	2.6	1.3
	CO	0.24	0.12
	TSP	0.90	0.45
	HC	0.30	0.15
Carbon dioxide regenerator	Ammonia	2.0	1.0
	CO	2.0	1.0
	CO_2	2440.0	1220.0
	HC	0.94	0.47
	Monoethanolamine	0.1	0.05
Condensate stripper	Ammonia	2.2	1.1
	CO_2	6.8	3.4
	Methanol	1.2	0.6

[a] Intermittent source, average 10 hours once every 30 days.

[b] Worst case assumption, that all sulfur entering tank is emitted during regeneration.

[c] Normalized to a 24 hour emission factor.

[d] Total HC in methane equivalents, species undetermined. Expected emissions are methane (Reference 1, p. 13).

Reference for Section 5.2

1. G. D. Rawlings and R. B. Reznik, Source Assessment: Synthetic Ammonia Production, EPA-600/2-77-107m, U. S. Environmental Protection Agency, Research Triangle Park, NC, November 1977.

5.3 CARBON BLACK

Audrey McBath

5.3.1 Process Description

Carbon black is produced by the reaction of a hydrocarbon fuel such as oil or gas with a limited supply of combustion air at temperatures of 2400 to 2800°F (1320 to 1540°C). The unburned carbon is collected as an extremely fine black, fluffy particle, 10 to 500 nm diameter. The principal uses of carbon black are as a reinforcing agent in rubber compounds (especially tires) and as a black pigment in printing inks, surface coatings, paper and plastics. Two major processes are presently used in the United States to manufacture carbon black-- the oil furnace process and the thermal process. The oil furnace process accounts for about 90 percent of production, and the thermal about 10 percent. Two others, the lamp process for production of lamp black and the cracking of acetylene to produce acetylene black, are each used at one plant in the U. S. However, these are small volume specialty black operations which constitute less than 1 percent of total production in this country. The gas furnace process is being phased out, and the last channel black plant in the U. S. was closed in 1976.

5.3.1.1 Oil Furnace Process-- In the oil furnace process (Figure 5.3-1 and Table 5.3-1), an aromatic liquid hydrocarbon feedstock is preheated and injected continuously into the combustion zone of a natural gas fired furnace, where it is decomposed to form carbon black. Primary quench water cools the gases to 1000°F (540°C) to stop the cracking. The exhaust gases entraining the carbon particles are further cooled to about 450°F (230°C) by passage through heat exchangers and direct water sprays. The black is then separated from the gas stream, usually by a fabric filter. A cyclone for primary collection and particle agglomeration may precede the filter. A single collection system often serves several manifolded furnaces.

The recovered carbon black is finished to a marketable product by pulverizing and wet pelletizing to increase bulk density. Water from the wet pelletizer is driven off in a gas fired rotary dryer. Oil or process gas can be used. From 35 to 70 percent of the dryer combustion gas is

charged directly to the interior of the dryer, and the remainder acts as an indirect heat source for the dryer. The dried pellets are then conveyed to bulk storage. Process yields range from 35 to 65 percent, depending on the feed composition and the grade of black produced. Furnace designs and operating conditions determine the particle size and the other physical and chemical properties of the black. Generally, yields are highest for large particle blacks and lowest for small particle blacks.

5.3.1.2 Thermal Process-- The thermal process is a cyclic operation in which natural gas is thermally decomposed into carbon particles, hydrogen, methane and a mixture of other organics. To start the cycle, a stoichiometric mixture of air and fuel gas is burned to heat a brick checkerwork in the process furnace to about 2400°F (1300°C). The air and fuel supply is then cut off, the furnace stack is closed, and natural gas is introduced into the furnace. The natural gas is decomposed by the heat from the hot bricks. When the bricks cool, the gas is shut off. The effluent gases containing the thermal black particles are flushed out of the furnace and cooled by water sprays to about 250°F (125°C) before passing through cyclonic collectors and fabric filters to recover the black.

The effluent gases, consisting of about 90 percent hydrocarbon, 6 percent methane and 4 percent higher hydrocarbons, are cooled, compressed and used as a fuel to reheat the furnaces. Normally, more than enough hydrogen is produced to make the thermal black process self-sustaining, and the surplus hydrogen is used to fire boilers that supply process steam and electric power.

The collected thermal black is pulverized and pelletized to a final product in much the same manner as is furnace black. Thermal process yields are generally high (35 to 60 percent), but the relatively coarse particles produced, 180 to 470 nm, do not have the strong reinforcing properties required for rubber products.

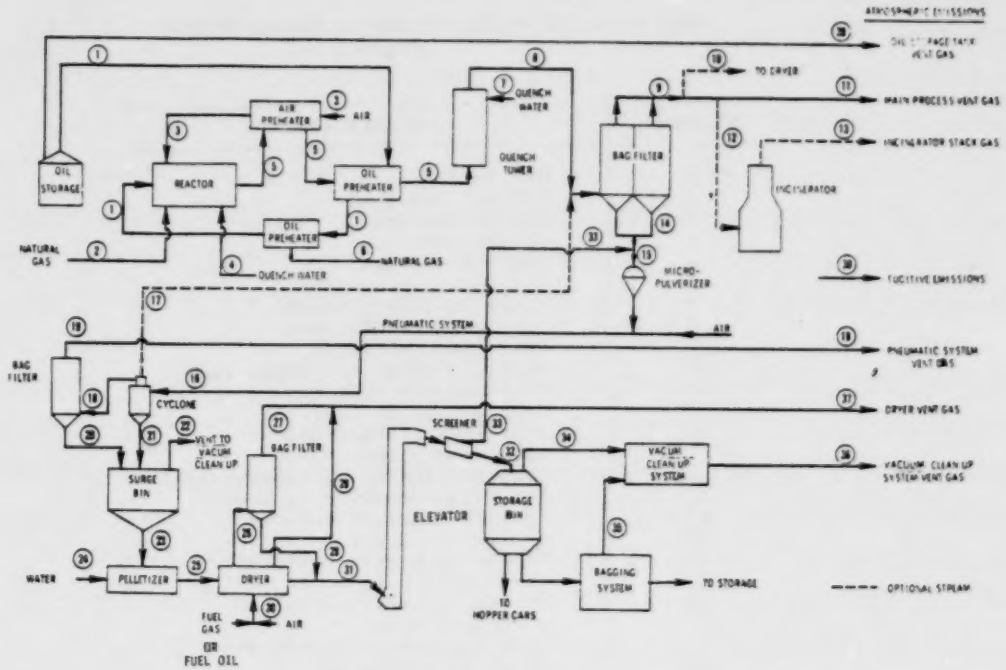

Figure 5.3-1. Flow diagram for the oil furnace carbon black process.

TABLE 5.3-1 STREAM CODE FOR THE OIL FURNACE PROCESS
(Figure 5.3-1)

Stream	Identification
1	Oil feed
2	Natural gas feed
3	Air to reactor
4	Quench water
5	Reactor effluent
6	Gas to oil preheater
7	Water to quench tower
8	Quench tower effluent
9	Bag filter effluent
10	Vent gas purge for dryer fuel
11	Main process vent gas
12	Vent gas to incinerator
13	Incinerator stack gas
14	Recovered carbon black
15	Carbon black to micropulverizer
16	Pneumatic conveyor system
17	Cyclone vent gas recycle
18	Cyclone vent gas
19	Pneumatic system vent gas
20	Carbon black from bag filter
21	Carbon black from cyclone
22	Surge bin vent
23	Carbon black to pelletizer
24	Water to pelletizer
25	Pelletizer effluent
26	Dryer direct heat source vent
27	Dryer bag filter vent
28	Carbon black from dryer bag filter
29	Dryer indirect heat source vent
30	Hot gases to dryer
31	Dried carbon black
32	Screened carbon black
33	Carbon black recycle
34	Storage bin vent gas
35	Bagging system vent gas
36	Vacuum cleanup system vent gas
37	Dryer vent gas
38	Fugitive emissions
39	Oil storage tank vent gas

5.3.2 Emissions and Controls

5.3.2.1 Oil Furnace Process-- Emissions from carbon black manufacture include particulate matter, carbon monoxide, organics, nitrogen oxides, sulfur compounds, polycyclic organic matter (POM) and trace elements.

The principal source of emissions in the oil furnace process is the main process vent. The vent stream consists of the reactor effluent and the quench water vapor vented from the carbon black recovery system. Gaseous emissions may vary considerably, according to the grade of carbon black being produced. Organic and CO emissions tend to be higher for small particle production, corresponding with the lower yields obtained. Sulfur compound emissions are a function of the feed sulfur content. Tables 5.3-2 and 5.3-3 show the normal emission ranges to be expected, with typical average values.

Particulates, sulfur oxides and nitrogen oxides are also emitted from the dryer vent. The oil feedstock storage tanks are a source of organic emissions. Carbon black emissions also occur from the pneumatic transport system vent, the plantwide vacuum cleanup system vent, and from cleaning, spills and leaks (fugitive emissions).

Gaseous emissions from the main process vent may be controlled with CO boilers, incinerators or flares. The pellet dryer combustion furnace, which is, in essence, a thermal incinerator, may also be employed in a control system. CO boilers, thermal incinerators or combinations of these devices can achieve essentially complete oxidation of organics and can oxidize sulfur compounds in the process flue gas. Combustion efficiencies of 99.6 percent for hydrogen sulfide and 99.8 percent for carbon monoxide have been measured for a flare on a carbon black plant. Particulate emissions may also be reduced by combustion of some of the carbon black particles, but emissions of sulfur dioxide and nitrogen oxides are thereby increased.

5.3.2.2 Thermal Process-- A comparison of the thermal and oil furnace processes indicates that emissions from the former are generally less severe. Nitrogen oxides, carbon monoxide and particulates are emitted from the furnace when stacks are open during the heating part of the

TABLE 5.1-7 EMISSION FACTORS FOR CARBON BLACK MANUFACTURE

EMISSION FACTOR RATING: B(OIL FURNACE PROCESS)

C(THERMAL PROCESS)

Process	Particulate[i]		Carbon Monoxide		Hydrocarbons[j]		Nitrogen Oxides		Sulfur Oxides		Hydrogen Sulfide	
	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT
Oil Furnace Process[a]												
Main Process Vent												
Uncontrolled	6.53 (0.2-10)	3.27[d] (0.1-5)	2,800 ± 19%[e] (1,400-4,400)	1,400 ± 19%[b] (700-2,200)	100 ± 40%[e] (20-300)	50 ± 40%[b] (10-159)	0.56 ± 15%[b] (2-5.6)	0.28 ± 15% (1-2.8)	0 (0-24)	0[b,l] (0-12)	60 ± 62%[e] 10S-265	30 ± 62%[b] 5S-135[m]
Flare[c]	2.70 (2.4-3)	1.35 (1.2-1.5)	245 (216-274)	122 (108-137)	3.7 (3.4-4)	1.85 (1.7-2)	NA	NA	50 (44-56)	25 (21.9-28)	2	1
Internal Combustion[d]	2.07	1.04	1.75	0.88	1.98	0.99	9.3	4.65	35.2	17.5	0.22	0.11
Dryer Vent												
Uncontrolled[c]	0.45 (0.10-0.80)	0.23 (0.05-0.40)							0.10	0.05		
Bag Filter[c,e]	0.24 ± 83% (0.02-0.80)	0.12 ± 83% (0.01-0.40)					0.73 (0.24-1.22)	0.36 (0.12-0.61)	0.52 (0.06-1.08)	0.26 (0.03-0.54)		
Scrubber[c]	0.71 (0.02-1.40)	0.36 (0.01-0.70)					2.20	1.10	0.40	0.20		
Pneumatic System Vent[c,e]												
Bag Filter	0.58 ± 93% (0.12-1.40)	0.29 ± 93% (0.06-0.70)										
Oil Storage Tank Vent[f]												
Uncontrolled					1.44	0.72						
Vacuum Cleanup System Vent[c,e]												
Bag Filter	0.06 ± 58% (0.02-0.10)	0.03 ± 58% (0.01-0.05)										
Fugitive Emissions[c]	0.20	0.10										
Solid Waste Incinerator[g]	0.24	0.12	0.02	0.01	0.02	0.01	0.08	0.04	0.02	0.01		
Thermal Process[h]	Neg	Neg	Neg	Neg	Neg	Neg	Unknown	Unknown	Neg	Neg	Neg	Neg

[a]Blanks indicate no emissions. All plants use bag filters on all process trains for product recovery except solid waste incineration.

[b]Average values are based on results of six sampling runs conducted by Monsanto Research Corporation at a representative plant with the industry mean production rate of 5.1×10^4 MT/yr (5.6×10^4 ton/yr). The corresponding error bounds represent 95% confidence limits. The ranges of values are based on a survey of fifteen plants in Reference 4.

[c]Average values and the corresponding ranges of values are based on a survey of plants in Reference 4 and the public files of Louisiana Air Control Commission.

[d]These are average values based on surveys of plants in References 4 and 5.

[e]Error bounds represent 95% confidence limits for corresponding mean values. Where no error bounds are given, data was insufficient to calculate.

[f]Emission factor calculated using empirical correlations for petrochemical losses from storage tanks (vapor pressure = 0.7 kPa).

[g]Based on emission rates obtained from the National Emission Data System. All plants do not use solid waste incineration. See Section 2.1.

[h]Emissions data are not available, but all emissions are believed to be negligible.

[i]The particulate matter is carbon black.

[j]Total non-methane hydrocarbons. Individual organic species are included in Table 5.3.3.

[k]Not available.

[l]Not detected at detection limit of 1 ppm.

[m]S is the weight percent sulfur in the feed.

TABLE 5.3-3. EMISSION FACTORS FOR CHEMICAL SUBSTANCES FOR OIL FURNACE CARBON BLACK MANUFACTURE

Chemical Substance	Main Process Vent Gas[a]	
	lb/ton	kg/MT
Carbon Disulfide	60 ± 76%	30 ± 76%
Carbonyl Sulfide	20 ± 99%	10 ± 99%
Methane	50 ± 47% (20-120)	25 ± 47% (10-60)
Acetylene	90 ± 48% (10-260)	45 ± 48% (5-130)
Ethane	0[b]	0[b]
Ethylene	3.2 ± 85%	1.6 ± 85%
Propylene	0[b]	0[b]
Propane	0.46 + 109% - 100%	0.23 + 109% - 100%
Isobutane	0.20 ± 80%	0.10 ± 80%
n-Butane	0.54 ± 57%	0.27 ± 57%
n-Pentane	0[b]	0[b]
POM	0.004 ± 52%	0.002 ± 52%
Trace Elements[c]	<0.50 ± 43%	<0.25 ± 43%

[a]These chemical substances are emitted only from the main process vent. Average values are based on six sampling runs made at a representative plant given in Reference 1. The corresponding error bounds represent 95% confidence limits for the mean values. The ranges given in parentheses are based on results of a survey of operating plants given in Reference 4.

[b]Not detected at detection limit of 1 ppm.

[c]Included are beryllium, lead, and mercury among several others.

process. During the production cycle, the process operates as a closed system, and no emissions occur except possibly through leaks. Nitrogen oxides may be formed, since high temperatures are reached in the furnaces. Carbon monoxide emissions result from oxidation. Particulate matter is emitted when loose carbon black deposited on the checkerbrick is released to the atmosphere in the form of puffs, which occur at five minute intervals as the furnace is switched from carbon black production to heating.

Emissions from the dryer vent, the pneumatic transport system vent, the vacuum cleanup system vent, and fugitive sources are similar to those for the oil furnace process, since the operations which give rise to these emissions in the two processes are similar. There is no emission point in the thermal process which corresponds to the oil storage tank vents in the oil furnace process. Also in the thermal process, sulfur compounds, POM, trace elements and organic compound emissions are minimal, because low sulfur natural gas is used, and the process off-gas is burned as fuel.

References for Section 5.3

1. R. W. Serth and T. W. Hughes, Source Assessment: Carbon Black Manufacture, EPA-600/2-77-107k, U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1977.
2. Air Pollutant Emission Factors, NAPCA Contract No. CPA-22-69-119, Resources Research, Inc., Reston, VA, April 1970.
3. I. Drogin, "Carbon Black", Journal of the Air Pollution Control Association, 18:216-228, April 1968.
4. Engineering and Cost Study of Air Pollution Control for the Photochemical Industry, Vol. 1: Carbon Black Manufacture by the Furnace Process, EPA-450/3-73-006a, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1974.
5. Kent C. Hustvedt and Leslie B. Evans, Standards Support and Emission Impact Statement: An Investigation of the Best Systems of Emission Reduction for Furnace Process Carbon Black Plants in the Carbon Black Industry (Draft), U. S. Environmental Protection Agency, Research Triangle Park, NC, April 1976.
6. Source Testing of a Waste Heat Boiler, EPA-75-CBK-3, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1975.

5.22 LEAD ALKYL

by Jake Summers, EPA,
and Pacific Environmental Services

5.22.1 Process Description[1]

Two alkyl lead compounds, tetraethyl lead (TEL) and tetramethyl lead (TML), are used as antiknock gasoline additives. Over 75 percent of the 1973 additive production was TEL, more than 90 percent of which was made by alkylation of sodium/lead alloy.

Lead alkyl is produced in autoclaves by the reaction of sodium/lead alloy with an excess of either ethyl (for TEL) or methyl (for TML) chloride in the presence of acetone catalyst. The reaction mass is distilled to separate the product, which is then purified, filtered and mixed with chloride/bromide additives. Residue is sluiced to a sludge pit, from which the bottoms are sent to an indirect steam dryer, and the dried sludge is fed to a reverberatory furnace to recover lead.

Gasoline additives are also manufactured by the electrolytic process, in which a solution of ethyl (or methyl) magnesium chloride and ethyl (or methyl) chloride is electrolyzed with lead metal as the anode.

5.22.2 Emissions and Controls[1]

Lead emissions from the sodium/lead alloy process consist of particulate lead oxide from the recovery furnace (and, to a lesser extent, from the melting furnace and alloy reactor), alkyl lead vapor from process vents, and fugitive emissions from the sludge pit.

Emissions from the lead recovery furnace are controlled by fabric filters or wet scrubbers. Vapor streams rich in lead alkyl can either be incinerated and passed through a fabric filter or be scrubbed with water prior to incinerating.

Emissions from electrolytic process vents are controlled by

using an elevated flare and a liquid incinerator, while a scrubber with toluene as the scrubbing medium controls emissions from the blending and tank car loading/unloading systems.

Table 5.22-1. LEAD ALKYL MANUFACTURE LEAD EMISSION FACTORS[a]
(EMISSION FACTOR RATING: B)

Process	Lead Emission Factor		References
	kg/10^3 kg produced	lb/ton produced	
Electrolytic process	0.5	1.0	1,2,3
Sodium/lead alloy process			
Recovery furnace	28	55	1,2,4
Process vents, TEL	2	4	1
Process vents, TML	75	150	1
Sludge pits	0.6	1.2	1

[a]No other pollutant factors available

Table 5.22-2. LEAD ALKYL MANUFACTURE CONTROL EFFICIENCIES[a]

Process	Control	Percent Reduction
Sodium/lead alloy process	Fabric filter	99+
	Low energy wet scrubber	80-85
	High energy wet scrubber	95-99

[a]Reference 1

References for Section 5.22

1. Background Information in Support of the Development of Performance Standards for the Lead Additive Industry, EPA Contract No. 68-02-2085, PEDCo-Environmental Specialists, Inc., Cincinnati, OH, January 1976.

2. Control Techniques for Lead Air Emissions, EPA-450/2-77-012, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1977.

3. W. E. Davis, Emissions Study of Industrial Sources of Lead Air Pollutants, 1970, EPA Contract No. 68-02-0271, W. E. Davis and Associates, Leawood, KS, April 1973.

4. R. P. Betz, et al., Economics of Lead Removal in Selected Industries, EPA Contract No. 68-02-0611, Battelle Columbus Laboratories, Columbus, OH, August 1973.

6.13 BREAD BAKING

Tom Lahre

6.13.1 General[1,2]

Bakery products generally can be divided into two groups: products leavened by yeast and products chemically leavened by baking powder. Other than yeast bread, which comprises the largest fraction of all yeast leavened baking production, leavened products include sweet rolls, crackers, pretzels, etc. Examples of chemically leavened baking products are cakes, cookies, cake doughnuts, corn bread and baking powder biscuits.

Bread is generally produced by either the straight-dough process or the sponge-dough process. In the straight-dough process, the ingredients are mixed, allowed to ferment, and then baked. In the sponge-dough process, only part of the ingredients are initially mixed and allowed to ferment, with the remainder added to the mix and fermented just prior to baking. The sponge-dough process is most often used by commercial bakeries.

In a commercial bakery, bread dough is fermented from two to four hours prior to baking at about $450^{o}F$. The temperature inside the bread does not exceed $212^{o}F$. The ovens used are predominately direct fired by natural gas. In such ovens, any vapors driven off the bread and any combustion product gases are removed through the same exhaust vent.

6.13.2 Emissions[1,2]

In the leavening process, yeast metabolizes the sugars and starches in the bread dough. During this fermentation stage, various chemical reactions take place, with the end products being primarily carbon dioxide (CO_2) and ethanol (C_2H_5OH). The carbon dioxide is necessary to leaven the dough, thereby increasing its volume. The byproduct ethanol, however, evaporates and leaves the dough. The rate of ethanol production depends on dough temperature, quantity of sweetner and type of yeast.

Laboratory experiments[1] and theoretical estimates[2] suggest that ethanol emissions from the sponge-dough process may range from 5 to 8 pounds per 1000 pounds of bread produced, whereas ethanol emissions from the straight-dough process are only 0.5 pounds per 1000 pounds produced.

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These factors include ethanol evaporation from all phases of bread production, although most of the emissions occur during baking. Negligible quantities of ethanol remain in the bread following baking. Several other nonmethane volatile organic compounds are also emitted from bread production, but in much smaller amounts. The reader should consult References 1 and 2 for details on how these emission factors are derived.

No controls or process modifications are employed to reduce ethanol emissions from bakeries. Some fraction of the ethanol emitted during baking could potentially be destroyed in the direct fired gas ovens, but since the ethanol does not come into contact with the flame zone, this fraction is thought to be insignificant.

References for Section 6.13

1. R. M. Keller, Nonmethane Organic Emissions from Bread Producing Operations, EPA-450/4-79-001, U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1978.

2. D. C. Henderson, "Commercial Bakeries as a Major Source of Reactive Volatile Organic Gases", Emission Inventory/Factor Workshop: Volume I, EPA-450/3-78-042a, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1978.

6.14 UREA

Frank Noonan

6.14.1 General[1]

Urea ($CO[NH_2]_2$) is produced by reacting ammonia and carbon dioxide to form ammonium carbamate ($NH_2CO_2NH_4$), which is then dehydrated to form urea. There are over fifteen production methods which can carry out these reactions. While the basics of the processes are the same, variations occur in vessel design, operating conditions, and type and quantity of recycle of unreacted material. The aqueous solution produced by these processes contains approximately 70 percent urea, and the solution may be sold as is or in solid form.

In the solidification procedure, urea solution is first concentrated in crystallizer or evaporator and then solidified. If in a crystallizer, the crystals are melted and then formed into a solid. If an evaporator is used, it produces a concentrate which is then solidified. In either case, solid urea is formed by prilling or granulation. Additional granular strength and packing resistance are obtained by two methods. In the first, used by about 50 percent of the plants and involving about 9 percent of all solid urea produced, formaldehyde or a phosphate based additive is injected into the fluid material before solid formation. In the second, the sized solid particles are coated with a clay substance. The finished product is usually stored in bulk, shipped in railroad hoppers or trucks, or bagged in 20.4 kg or 36.3 kg sacks. In addition, some urea solution may be transported by pipeline, and some solid by river barge.

Figure 6.14-1 is a flow diagram of the solid urea production process.

6.14.2 Emissions[1]

Emissions from urea manufacture consist of ammonia and particles of solid urea. In solution production, they issue from the bulk loading of the product, and in solid production, they come from the evaporator, prilling tower, granulator, product finishing, bagging and loading, and bulk loading points. The prilling tower and granulator are both emission points, but are alternate, not sequential, steps in the process.

Table 6.14-1. EMISSION FACTORS FOR UREA PRODUCTION[a,b]
(EMISSION FACTOR RATING: A)

Emitting Operation	Emission Factor					
	Ammonia			Particulate		
	lb/ton		kg/MT	lb/ton		kg/MT
Solution concentration (controlled)	3.46	(±64%)	1.73	0.214	(±28%)	0.107
Prilling (uncontrolled)	0.80	(±84%)	0.40	3.20	(±17%)	1.60
Granulation	0.50	(±48%)	0.25	0.168 to 0.40	(±29%) (±25%)	0.084 to 0.20
Solid product finishing	-		-	<4.00		<2.00
Solution product bulk loading	0.24		0.12	-		-
Solid product bagging and bulk loading	-		-	< 0.30		< 0.15

[a]Dashes indicate no emissions from operation.

[b]Percentages represent 95% confidence interval.

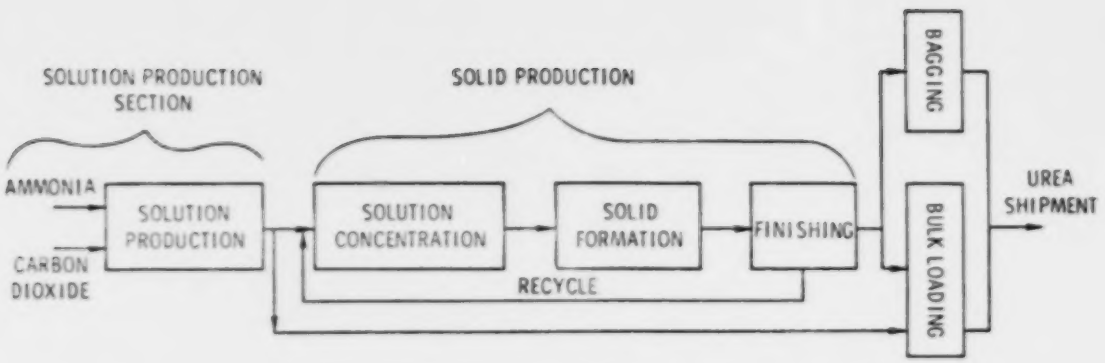

Figure 6.14-1. Urea production process.

6.14.3 Controls[1]

Applied control technology for the urea industry varies from plant to plant. In the concentration section, emissions are controlled by condensing the evaporator overheads and sewering or selling the product, or by passing the stream through a scrubber. In the solid formation section, control technology depends on the formation process used. In granulation processes, scrubbers are used to control emissions and to recover entrained product. In prilling processes, about 50 percent of the industry uses some form of packed scrubber for control. The others exhaust emissions to the atmosphere. Further technology has not been widely proven. At least [illegible]ompanies are currently trying to develop or to test technology which will reduce prilling tower emissions effectively.

Reference for Section 6.14

1. W. J. Search and R. B. Resnik, Source Assessment: Urea Manufacture, EPA-600/2-77-107ℓ, U. S. Environmental Protection Agency, Research Triangle Park, NC, November 1977.

6.15 BEEF CATTLE FEEDLOTS

Tom Lahre

6.15.1 General[1]

A beef cattle feedlot is an area in which beef animals are confined for fattening prior to marketing. This fattening, or finish feeding, typically lasts four to five months, during which time the cattle are fed a high energy ration of feed grains and/or forage.

Cattle feedlots range in capacity from several head up to 100,000 cattle. Of the 146,000 beef cattle feedlots in the U.S. in 1973, 2,040 feedlots had a capacity of more than 1,000 head, marketing 65 percent of all finish fed beef cattle. Animal density in feedlots is generally in the range of 12,500 to 125,000 head/km^2.

During its stay in a feedlot, a beef animal will produce over 450 kg of manure (dry weight). Wet manure production is typically about 27 kg per day per head, usually deposited on less than 20 m^2 of surface. Because of the prodigious quantity of manure produced in a feedlot, periodic removal is necessary to prevent unacceptable accumulations. Most cattle manure is applied to nearby land as fertilizer for feed grain production, while some is lagooned, dumped on wastelands, or disposed of through incineration, liming, or pitting. Manure removal frequencies are dictated in part by climatic conditions, animal comfort, labor scheduling, and air and water pollution control potentials. Typically, manure removal is conducted from one to three times per year. When disposal is not immediately possible after removal, the manure may be stockpiled on a nearby open site.

The leading states in the industry are Texas, Nebraska, Iowa, Kansas, Colorado, California, and Illinois. These states contribute 75 percent of all feed cattle marketed and contain 72 percent of the feedlots greater than 1000 head capacity. Feedlots are generally located in low population density regions with access to major transportation routes.

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6.15.2 Emissions and Controls[1]

Air pollution from feedlots originates from several points in a feedlot operation, including the holding pens, runoff holding ponds, and alleyways between pens. Major pollutants of concern include fugitive particulate, ammonia and various malodorous gases.

Fugitive particulate is generated several ways. Cattle movement within the holding pens is a primary source. Dust is also generated by wind acting on the dried surfaces and by vehicular traffic on alleyways among the pens. Fugitive particulate emissions from feedlots are composed largely of soil dust and dried manure. The potential for dust generation is greatly increased during prolonged dry periods (e.g., from late spring to midsummer in the Southwest), and when a loose, dry pad of soil and manure is allowed to build up in the pens.

Ammonia is the predominant gaseous pollutant emitted from feedlots. Ammonia is a result of anaerobic decomposition of feedlot surfaces as well as volatilization from urine. Ammonia emissions are generally increased when conditions favor anaerobic decay. For example, although 25 to 40 percent moisture levels are necessary on feedlot surfaces for aerobic decomposition (which is odorless), too much rain or watering, resulting in puddling and wet spots, can trigger increased ammonia production. Ammonia formation may also occur when anaerobic conditions exist in the manure stockpiles and runoff holding ponds. In general, higher ammonia emissions are associated with higher temperatures and humidity, overly wet conditions, and feedlot disturbances such as mounding or manure removal.

A number of extremely odorous compounds (amines, sulfides, mercaptans) may also result from anaerobic decomposition of solid manure beneath the feedlot surface as well as in the runoff holding ponds. Generally, the same conditions that favor ammonia production will enhance the evolution of these other gases, as well.

No air pollutant control devices are applied to feedlots because of the fugitive nature of the emissions. The most effective controls involve various housekeeping measures designed to eliminate conditions that favor the generation of dust and odors. For example, measures that help to maintain sufficient moisture levels in the feedlot surface areas and manure stockpiles will reduce the generation of dust. One of the most effective dust control techniques is periodic application of water to the dry feedlot surface, either by permanent sprinkling systems or mobile tank trucks. However, care must be taken to avoid overwatering, which can cause wet spots conducive to anaerobic decay and subsequent malodors. Increasing the cattle density in the pens may also help maintain high enough moisture levels to limit particulate generation. In addition, some dust control is effected by minimizing the accumulation of dry and pulverized manure on the surfaces of the feedlots. A maximum depth of 2 to 8 cm of loose, dry manure is recommended for increasing the effectiveness of dust control procedures.

Odor and ammonia control are best effected by housekeeping measures that enhance aerobic rather than anaerobic decomposition of the cattle wastes. For example, besides reducing dust emissions, sprinkling provides moisture for aerobic biodegradation of the manure. Good drainage must be provided, however, and overwatering must be avoided. Deep accumulations of manure of slurry consistency can optimize anaerobic conditions. Hence, feedlot surfaces should be periodically scraped to remove such accumulations. Scraping should be done carefully so that only the surface layer is disturbed. Manure stockpiles should not be allowed to get too large, too wet, or encrusted, and they should be disposed of within four or five days. If the stockpiles are composted, the manure should be piled in long narrow windrows to allow access for turning the piles to promote aerobic conditions and to enable rapid control of spontaneous combustion

fires. Anaerobic conditions can be reduced in runoff holding ponds by removing solids from the runoff, by adding more water to the ponds to dilute the nutrient content, and by aeration of the surface. Runoff water also may be treated chemically to suppress the release of malodorous gases.

Emission factors for feedlot operations are shown in Table 6.15-1. These factors should be considered at best to be crude estimates of potential emissions from feedlots where no measures are employed to control dust or odors. The limitations of these factors are more fully discussed in the footnote to Table 6.15-1. The reader should consult Reference 1 for a detailed discussion of the emissions and control information available on beef cattle feedlots.

Table 6.15-1 EMISSION FACTORS FOR BEEF CATTLE FEEDLOTS[a]
(EMISSION FACTOR RATING: E)

Pollutant	Feedlot capacity basis lb (kg) per day per 1000 head capacity	Feedlot throughput basis ton (metric ton) per 1000 head throughput
Particulate[b]	280 (130)	27 (25)
Ammonia[c]	11 (5)	1.1 (1)
Amines[c]	0.4 (0.2)	0.044 (0.04)
Total sulfur compounds[c]	1.7 (0.8)	0.15 (0.14)

[a]These factors represent general feedlot operations with no housekeeping measures for air pollution control. Because of the limited data available on emissions and the nature of the techniques utilized to develop emission factors, Table 6.15-1 should only be used to develop order-of-magnitude estimates of feedlot emissions. All factors are based on information compiled in Reference 1.

[b]These factors represent emissions during a dry season at a feedlot where watering as a dust control measure would not be a common practice. No data are available to estimate emission factors for feedlots during periods of abundant precipitation or where watering and other housekeeping measures are employed for dust control.

[c]These factors represent emission factors for feedlots that have not been chemically treated and where no special housekeeping measures are employed for odor control.

Reference for Section 6.15

1. J. A. Peters and T. R. Blackwood, Source Assessment: Beef Cattle Feedlots, EPA-600/2-77-107, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1977.

6.16 DEFOLIATION AND HARVESTING OF COTTON

Rob McConnell

6.16.1 General

Wherever it is grown in the U.S., cotton is defoliated or disiccated prior to harvest. Defoliants are used on the taller varieties of cotton which are machine picked for lint and seed cotton, while desiccants usually are used on short, stormproof cotton varieties of lower yield that are harvested by mechanical stripper equipment. More than 99 percent of the national cotton area is harvested mechanically. The two principal harvest methods are machine picking, with 70 percent of the harvest from 61 percent of the area, and machine stripping, with 29 percent of the harvest from 39 percent of the area. Picking is practiced throughout the cotton regions of the U.S., while stripping is limited chiefly to the dry plains of Texas and Oklahoma.

Defoliation may be defined as the process by which leaves are abscised from the plant. The process may be initiated by drought stress, low temperatures or disease, or it may be chemically induced by topically applied defoliant agents or by overfertilization. The process helps lodged plants to return to an erect position, removes the leaves which can clog the spindles of the picking machine and strain thefiber, accelerates the opening of mature bolls, and reduces boll rots. Desiccation by chemicals is the drying or rapid killing of the leaf blades and petioles, with the leaves remaining in a withered state on the plant. Harvest-aid chemicals are applied to cotton as water-based spray, either by aircraft or by a ground machine.

Mechanical cotton pickers, as the name implies, pick locks of seed cotton from open cotton bolls and leave the empty burs and unopened bolls on the plant. Requiring only one operator, typical modern pickers are self propelled and can simultaneously harvest two rows of cotton at a speed of 1.1 to 1.6 meters per second (2.5 - 3.6 mph). When the picker basket gets filled with seed cotton, the

machine is driven to a cotton trailer at the edge of the field. As the basket is hydraulically raised and tilted, the top swings open, allowing the cotton to fall into the trailer. When the trailer is full, it is pulled from the field, usually by pickup truck, and taken to a cotton gin.

Mechanical cotton strippers remove open and unopened bolls along with burs, leaves and stems from cotton plants, leaving only bare branches. Tractor-mounted, tractor-pulled or self propelled, strippers require only one operator. They harvest from one to four rows of cotton at speeds of 1.8 m/s to 2.7 m/s (4.0 - 6.0 mph). After the cotton is stripped, it enters a conveying system that carries it from the stripping unit to an elevator. Most conveyers utilize either augers or a series of rotating spike-toothed cylinders to move the cotton, accomplishing some cleaning by moving the cotton over perforated, slotted or wire mesh screen. Dry plant material (burs, stems and leaves) is crushed and dropped through openings to the ground. Blown air is sometimes used to assist cleaning.

6.16.2 Emissions and Controls

Emission factors for the drifting of major chemicals applied to cotton were compiled from literature and reported in Reference 1. In addition, drift losses from arsenic acid spraying were developed by field testing. Two off-target collection stations, with six air samplers each, were located downwind from the ground spraying operations. The measured concentration was applied to an infinite line source atmosphere diffusion model (in reverse) to calculate the drift emission rate. This was in turn used for the final emission factor calculation. The emissions occur from July to October, preceding by two weeks the period of harvest in each cotton producing region. The drift emission factor for arsenic acid is eight times lower than previously estimated, since Reference 1 used a ground rig rather than an airplane and because of the low volatility of arsenic acid.

Various methods of controlling drop size, proper timing of application, and modification of equipment are practices which can reduce drift hazards. Fluid additives have been used that increase the viscosity of the spray formulation, and thus decrease the number of fine droplets (<100 um). Spray nozzle design and orientation also control the droplet size spectrum. Drift emission factors for the defoliation or desiccation of cotton are listed in Table 6.16-1.

Three unit operations are involved in mechanical harvesting of cotton: harvesting, trailer loading (basket dumping) and transport of trailers in the field. Emissions from these operations are in the form of solid particulates. Particulate emissions (<7 um mean aerodynamic diameter) from these operations were developed in Reference 2. The particulates are composed mainly of raw cotton dust and solid dust, which contains free silica. Minor emissions include small quantitites of pesticide, defoliant and desiccant residues that are present in the emitted particulates. Dust concentrations from harvesting were measured by following each harvesting machine through the field at a constant distance directly downwind from the machine, while staying in the visible plume centerline. The procedure for trailer loading was the same, but since the trailer is stationary while being loaded, it was necessary only to stand a fixed distance directly downwind from the trailer while the plume or puff passed over. Readings were taken upwind of all field activity to get background concentrations. Particulate emission factors for the principal types of cotton harvesting operations in the U.S. are shown in Table 6.16-2. The factors are based on average machine speed of 1.34 m/s (3.00 mph) for pickers and 2.25 m/s (5.03 mph) for strippers, on a basket capacity of 109 kg (240 lb), on a trailer capacity of 6 baskets, on a lint cotton yield of 63.0 metric tons/km^2 (1.17 bale/acre) for pickers and 41.2 metric tons/km^2 (.77 bale/acre) for strippers, and on a transport speed of 4.47 m/s (10.0 mph). Analysis of particulate samples showed average free silica content of 7.9 percent for mechanical cotton picking and 2.3 percent for mechanical

cotton stripping. Estimated maximum percentages for pesticides, defoliants and desiccants from harvesting are also noted in Table 6.16-2. No current cotton harvesting equipment or practices provide for control of emissions. In fact, equipment design and operating practices tend to maximize emissions. Preharvest treatment (defoliation and desiccation) and harvest practices are timed to minimize moisture and trash content, so they also tend to maximize emissions. Soil dust emissions from field transport can be reduced by lowering vehicle speed.

Table 6.16-1. EMISSION FACTORS FOR DEFOLIATION OR DESICCATION OF COTTON[a]

(EMISSION FACTOR RATING: C)

Pollutant	Emission Factor[b]	
	lb/ton	g/kg
Sodium chlorate	20.0	10.0
DEF	20.0	10.0
Arsenic acid	12.2	6.1
Paraquat	20.0	10.0

[a] Reference 1

[b] Factor is in terms of quantity of drift per quantity applied.

Table 6.16-2 PARTICULATE EMISSION FACTORS FOR COTTON HARVESTING OPERATIONS[a]
(EMISSION FACTOR RATING: C)

	HARVESTING		TRAILER LOADING		TRANSPORT		TOTAL	
Type of harvester	$\frac{kg}{km^2}$	$\frac{lb}{mi^2}$	$\frac{kg}{km^2}$	$\frac{lb}{mi^2}$	$\frac{kg}{km^2}$	$\frac{lb}{mi^2}$	$\frac{kg}{km^2}$	$\frac{lb}{mi^2}$
Picker[d]								
Two-row, with basket	.46	2.6	.070	.40	.43	2.5	.96	5.4
Stripper[e]								
Two-row, pulled trailer	7.4	42	-[b]	-	.28	1.6	7.7	44
Two-row, with basket	2.3	13	.092	.52	.28	1.6	2.7	15
Four-row, with basket	2.3	13	.092	.52	.28	1.6	2.7	15
Weighted average[c]	4.3	24	.056	.32	.28	1.6	4.6	26

[a]Emission factors are from Reference 2 for particulate of <7um mean aerodynamic diameter.

[b]Not applicable

[c]The weighted average stripping factors are based on estimates that 2% of all strippers are four-row models with baskets, and of the remainder, 40% are two-row models pulling trailers and 60% are two-row models with mounted baskets.

[d]Free silica content is 7.9%; maximum content of pesticides and defoliants is 0.02%.

[e]Free silica content is 2.3%; maximum content of pesticides and desiccants is 0.2%.

References for Section 6.16

1. J. A. Peters and T. R. Blackwood, Source Assessment: Defoliation of Cotton-- State of the Art, EPA-600/2-77-107g, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1977.

2. J. W. Snyder and T. R. Blackwood, Source Assessment: Mechanical Harvesting of Cotton-- State of the Art, EPA-600/2-77-107d, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1977.

7.3 PRIMARY COPPER SMELTING

Charles Masser

7.3.3 Fugitive Emission Factors

Potential sources of fugitive particulate emissions in the copper industry are roasting, smelting, converting and fire refining. Table 7.3-3 shows the potential uncontrolled fugitive emission factors from these sources.

Fifteen percent of the particulate emissions from roasting are less than 10 μm, and 50 percent of those from reverberatory furnaces are less than 37 μm.[10,11] The mean particulate diameter of converter emissions is 44 μm. Sixteen percent of pouring and casting emissions are less than 10 μm, and 46 percent are less than 74 μm.[11]

Table 7.3-3. POTENTIAL FUGITIVE EMISSION FACTORS FOR UNCONTROLLED PRIMARY COPPER SMELTERS

(EMISSION FACTOR RATING: E)

Type of Operation	Particulates[a] lb/ton	Particulates[a] kg/MT
Roasting[b]	23.00	11.50
Reverberatory smelting furnace[c]	8.50	4.25
Converter[b,d]	10.50	5.25
Fire refining furnace (anode furnace and casting)[d,e]	1.90	0.95

[a] Factors expressed as units per units of end product.

[b] Based on material balance using same percentage estimated for SO_2 from Reference 12.

[c] Reference 13.

[d] Reference 14.

[e] Reference 15.

Additional References for Section 7.3

10. Control Techniques for Lead Air Emissions, EPA-450/2-77-012, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1978.

11. L. J. Shannon and P. G. Gorman, Particulate Pollutant System Study, Vol. III: Emission Characteristics, EPA Contract No. 22-69-104, Midwest Research Institute, Kansas City, MO, 1971.

12. Evaluation of the Controllability of Copper Smelters in the United States, EPA Contract No. 68-02-1354, Pacific Environmental Services, Inc., Santa Monica, CA, November 1974.

13. A Study of Fugitive Emissions from Metallurgical Processes, EPA Contract No. 68-02-2120, Midwest Research Institute, Kansas City, MO, November 1976.

14. Evaluation of Sulfur Dioxide and Arsenic Control Techniques for ASARCO: Tacoma Copper Smelter, EPA Contract No. 68-02-1321, PEDCo Environmental, Inc., Cincinnati, OH, September 1976.

15. Personal Communication from Herbert Z. Stuart, Phelps Dodge Corp., New York, NY, to Don R. Goodwin, Emission Standards and Engineering Division, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, 21 January 1977.

7.6a LEAD BEARING ORE CRUSHING AND GRINDING

by Jake Summers, EPA, and
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7.6a.1 Process Description

Lead and zinc ores are normally deep mined, whereas copper ores are open pit mined. Lead, zinc and copper are usually found together (in varying percentages) in combination with sulfur and/or oxygen.

In underground mines, the ore is disintegrated by percussive drilling machines, run through a primary crusher, and then conveyed to the surface. In open pit mines, ore and gangue are loosened and pulverized by explosives, scooped up by mechanical equipment, and transported to the concentrator.

Standard crushers, screens, and rod and ball mills classify and reduce the ore to powders in the 65 to 325 mesh range. The finely divided particles are separated from the gangue and are concentrated in a liquid medium by gravity and/or selective flotation, then cleaned, thickened and filtered. The concentrate is dried prior to shipment to the smelter.

7.6a.2 Emissions and Controls

Lead emissions are basically fugitive, caused by drilling, blasting, loading, conveying, screening, unloading, crushing and grinding. The primary means of control are good mining techniques and equipment maintenance. These practices include enclosing the truck loading operation, wetting or covering truck loads and stored concentrates, paving the road from mine to concentrator, sprinkling the unloading area, and preventing leaks in the crushing and griding enclosures. Cyclones and fabric filters can be used in the milling operations.

Particulate and sulfur dioxide emission factors for lead ore crushing and materials handling operations are given in Section 7.6a.2, Table 7.6a-1. Lead emissions from the mining and milling of copper ores are negligible.

Table 7.6a-1. EMISSION FACTORS FOR ORE CRUSHING AND GRINDING

(EMISSION FACTOR RATING: B)

Type of Ore	Particulate Emission Factor[a]		Lead Emission Factor[b]	
	lb/ton processed	kg/10^3 kg processed	lb/ton processed	kg/10^3 kg processed
Pb[c]	6.0	3.0	0.3	0.15
Zn	6.0	3.0	0.012	0.006
Cu	6.4	3.2	0.012	0.006
Pb-Zn	6.0	3.0	0.12	0.06
Cu-Pb	6.4	3.2	0.12	0.06
Cu-Zn	6.4	3.2	0.012	0.006
Cu-Pb-Zn	6.4	3.2	0.12	0.06

[a]Reference 1, pp. 4-39

[b]References 1-5

[c]Refer to Section 7.6

References for Section 7.6a

1. Control Techniques for Lead Air Emissions, EPA-450/2-77-012, U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1977.
2. W. E. Davis, Emissions Study of Industrial Sources of Lead Air Pollutants, 1970, EPA Contract No. 68-02-0271, W. E. Davis and Associates, Leawood, KS, April 1973.
3. Environmental Assessment of the Domestic Primary Copper, Lead, and Zinc Industry, EPA Contract No. 68-02-1321, PEDCO-Environmental Specialists, Inc., Cincinnati, OH, September 1976.
4. Communication with Mr. J. Patrick Ryan, Bureau of Mines, U. S. Department of the Interior, Washington, DC, September 9, 1976.
5. B. G. Wixson and J. C. Jennett, "The New Lead Belt in the Forested Ozarks of Missouri", Environmental Science and Technology, 9(13):1128-1133, December 1975.

7.9 SECONDARY COPPER SMELTING AND ALLOYING

Charles Masser

7.9.3 Fugitive Emission Factors

Potential sources of fugitive particulate emissions from secondary smelting and alloying operations are sweating, drying, insulation burning, smelting furnaces and casting. Table 7.9-2 shows these sources and their corresponding emission factors.

No data are presently available concerning size characteristics of the fugitive emissions.

Table 7.9-2. POTENTIAL FUGITIVE PARTICULATE EMISSION FACTORS FOR UNCONTROLLED COPPER SMELTING AND ALLOYING

(EMISSION FACTOR RATING: E)

TYPES OF OPERATION	Particulates[a] lb/ton	kg/MT
Sweating furnace[b]	0.75	0.38
Rotary dryer[b]	13.75	6.88
Insulation burning[c]	13.75	6.88
Electric induction furnace[d]	0.14	0.07
Reverberatory furnace[e]	5.27	2.64
Rotary furnace[d]	4.43	2.22
Crucible furnace[e]	0.49	0.25
Cupola (blast) furnace[e]	3.66	1.83
Casting[b]	0.015	0.008

[a]Factors are expressed as units per volume of scrap processed, except casting, which is expressed as units per volume cast.

[b]Engineering judgement assuming that fugitive emissions are equal to 5 percent of stack emissions shown in Reference 4.

[c]Engineering judgement assuming that fugitive emissions are equal to 5 percent of stack emission factor shown in Reference 5.

[d]Engineering judgement assuming that fugitive emissions are equal to 5 percent of stack emission factor shown in Reference 1.

[e]Engineering judgement, average of two sets of data, assuming that fugitive emissions are equal to 5 percent of stack emission factors shown in References 1 and 5.

Additional References for Section 7.9

4. Multimedia Environmental Assessment of the Secondary Nonferrous Metal Industry, Volume II: Industry Profile, EPA Contract No. 68-02-1319, Radian Corporation, Austin, TX, June 1976.

5. Particulate Pollutant System Study, Volume III: Handbook of Emission Properties, EPA Contract No. 22-69-104, Midwest Research Institute, Kansas City, MO, May 1971.

7.15 STORAGE BATTERY PRODUCTION

by Jake Summers, EPA, and
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7.15.1 Process Description

Lead/acid storage batteries are produced from lead alloy ingots and lead oxide. The latter may or may not be manufactured at the same plant (Section E.5).

Molten lead is pumped or flows directly from pot furnaces into the molds that form the battery grids. Batches of lead sulfate paste are blended by mixing lead oxide, water, sulfuric acid, an organic expander and other constituents. Pasting machines force the stiff mixture into the interstices of the grids (which are thereafter referred to as plates).

The plates are cured and stacked in an alternating positive and negative block formation, with insulators between them. They are then fastened together either by a burning operation (welding leads to the tabs of each pair of positive and negative plates) or by a "cast on strip" process (in which molten lead is poured around and between the plate tabs). Positive and negative terminals are then welded to each element, which can go to either the wet or dry battery assembly line. Pot furnaces are used for reclaiming defective lead parts.

7.15.2 Emissions and Controls[1]

Grid casting furnaces and machines, paste mixers, plate dryers, reclaim furnaces and parts casting machines can be controlled by low- to medium-energy impingement and entrainment scrubbers. "Three process" (element stacking, lead burning and battery casting) emissions can be controlled by pulse jet fabric filters. Waste material caught in control systems is recycled to recover the lead.

Table 7.15-1. STORAGE BATTERY PRODUCTION EMISSION FACTORS[a]
(EMISSION FACTOR RATING: B)

Process	Particulate Emission Factor		Lead Emission Factor	
	($kg/10^3$ batteries)	($lb/10^3$ batteries)	($kg/10^3$ batteries)	($lb/10^3$ batteries)
Grid casting	0.8	1.8	0.4	0.9
Paste mixing	1.0	2.2	0.5	1.1
Lead oxide mill (baghouse outlet)	0.10	0.24	0.05	0.12
Three-process operation[b]	13.2	29.2	6.6	14.6
Lead reclaim furnace	0.70	1.54	0.35	0.77
Small parts casting	0.09	0.19	0.05	0.77
Formation	14.0[c]	32.0[c]	N/A	N/A
Storage battery production (total)	29.9	67.2	8	17.6

[a]References 2-6

[b]Stacking, lead burning and battery assembly

[c]H_2SO_4

Table 7.15-2. STORAGE BATTERY PRODUCTION CONTROL EFFICIENCES[a]

Process	Control	Percent Reduction
Storage battery production (total)	Low to medium energy impingement and entrainment scrubbers	85 - 90+
	Pulse jet fabric filter	95 - 99+

[a]Reference 1

References for Section 7.15

1. Background Information in Support of the Development of Performance Standards for the Lead Additive Industry, PEDCo-Environmental Specialists, Inc., Cincinnati, OH, EPA Contract No. 68-02-2085, January 1976.

2. Control Techniques for Lead Air Emissions, EPA-450/2-77-012, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1977.

3. Screening Study To Develop Background Information and To Determine the Significance of Emissions from the Lead/Acid Battery Industry, EPA Contract No. 68-02-0299, Vulcan-Cincinnati, Inc., Cincinnati, OH, December 1972.

4. Confidential test data from a major battery manufacturer, July 1973.

5. Particulate and Lead Emission Measurements from Lead Oxide Plants, EPA Contract No. 68-02-0226, Monsanto Research Corp., Dayton, OH, August 1973.

6. Background Information in Support of the Development of Performance Standards for the Lead/Acid Battery Industry, Interim Report, EPA Contract No. 68-02-2085, PEDCo-Environmental Specialists, Inc., Cincinnati, OH, December 1975.

7.16 LEAD OXIDE AND PIGMENT PRODUCTION

by Jake Summers, EPA, and
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7.16.1 General

Lead oxide is used in the manufacture of lead/acid storage batteries (Section E.3) and as a pigment in paints. Black oxide, which is used exclusively in storage batteries, contains 60 to 80 percent litharge (PbO) the remainder being finely divided metallic lead.[1] The major lead pigment is red lead (Pb_3O_4), which is used principally in ferrous metal protective paints. Other lead pigments include white lead and lead chromates.

Most lead oxides and many lead pigments are derived from lead monoxide (PbO) in the form of litharge, which is produced by (1) partially oxidizing lead and milling it to a powder, which is then completely oxidized in a reverberatory furnace: (2) oxidizing and stirring pig lead in a reverberatory furnace or rotary kiln; (3) running molten lead into a cupelling furnace; or (4) atomizing molten lead in a flame. The product must be cooled quickly to below 300°C (572°F) to avoid formation of red lead.[2]

Black oxide is usually produced (in the same furnace in which the litharge is made) by either the ball mill or Barton process. Cyclones and fabric filters collect the product. Red lead is produced by oxidizing litharge in a reverberatory furnace. Basic carbonate white lead production is based on the reaction of litharge with acetic acid or acetate ions. White leads other than carbonates are made either by chemical or fuming processes. Chromate pigments are generally manufactured by precipitation or calcination.

7.16.2 Emissions and Controls

Automatic shaker type fabric filters, often preceded by cyclone mechanical collectors or settling chambers, are the almost universal choice for collecting lead oxides and pigments. Where fabric filters

are not appropriate, scrubbers are used, resulting in higher emissions. The ball mill and Barton processes of black oxide manufacturing recover the lead product by these two means. Collection of dust and fumes from the production of red lead is likewise an economic necessity, since particulate emissions, although small, are about 90 percent lead. Data on emissions from the production of white lead pigments are not available, but they have been estimated because of health and safety regulations. The emissions from dryer exhaust scrubbers account for over 50 percent of the total lead emitted in lead chromate production.

Table 7.16-1. LEAD OXIDE AND PIGMENT PRODUCTION EMISSION FACTORS[a]
(EMISSION FACTOR RATING: B)

Process	Particulate		Lead Emission Factor		References
	lb/ton produced	kg/10^3 kg produced	lb/ton produced	kg/10^3 kg produced	
Lead oxide production:					
Barton pot[b]	0.43-0.85	0.21-0.43	0.44	0.22	4,6,7
Calcining furnace	c	c	14.0	7.0	6
Pigment production:					
Red lead[b]	1.0[d]	0.5[d]	0.9	0.5	4,5
White lead[b]	c	c	0.55	0.28	4,5
Chrome pigments:	c	c	0.13	0.065	4,5

[a]Reference 4, pp. 4-283 and 4-287.

[b]Measured at baghouse outlet. Baghouse is considered process equipment.

[c]Data not available.

[d]Only PbO and oxygen used in red lead production, so particulate emissions assumed to be about 90% lead.

Table 7.16-2. LEAD OXIDE AND PIGMENT PRODUCTION CONTROL EFFICIENCIES

Process	Control	Percent Reduction
Lead oxide and pigment production	Mechanical shaker fabric filter (preceded by dry cyclone or settling chamber)	99[a]
	Scrubber	70-95[b]

[a]Reference 3

[b]Reference 4

References for Section 7.16

1. E. J. Ritchie, Lead Oxides, Independent Battery Manufacturers Association, Inc., Largo, FL, 1974.

2. W. E. Davis, Emissions Study of Industrial Sources of Lead Air Pollutants, 1970, EPA Contract No. 68-02-0271, W.E. Davis and Associates, Leawood, KS, April 1973.

3. Background Information in Support of the Development of Performance Standards for the Lead Additive Industry, EPA Contract No. 68-02-2085, PEDCo-Environmental Specialists, Inc., Cincinnati, OH, January 1976.

4. Control Techniques for Lead Air Emissions, EPA-450/2-77-012. U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1977.

5. R. P. Betz, et al., Economics of Lead Removal in Selected Industries, EPA Contract No. 68-02-0299, Battelle Columbus Laboratories, Columbus, OH, December 1972.

6. Emission Test No. 74-PB-O-1, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 1973.

7.17 MISCELLANEOUS LEAD PRODUCTS

by Jake Summers, EPA, and
Pacific Environmental Services

7.17.1 Type Metal Production

7.17.1.1 General

Lead type, used primarily in the letterpress segment of the printing industry, is cast from a molten lead alloy and remelted after use. Linotype and monotype processes produce a mold, while the stereotype process produces a plate for printing. All type metal is an alloy consisting of 60 to 85 percent recovered lead with antimony, tin and a small amount of virgin metal.

7.17.1.2 Emissions and Controls

The melting pot is the major source of emissions, containing hydrocarbons as well as lead particulates. Pouring the molten metal into the molds involves surface oxidation of the metal, possibly producing oxidized fumes, while the trimming and finishing operations emit lead particles. It is estimated that 35 percent of the total emitted particulate is lead.[1]

Approximately half of the current lead type operations control lead emissions, by about 80 percent. The other operations are uncontrolled.[2] The most frequently controlled sources are the main melting pots and drossing areas. Linotype equipment does not require controls when operated properly. Devices in current use on monotype and stereotype lines include rotoclones, wet scrubbers, fabric filters, and electrostatic precipitators, all which can be used in various combinations.

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7.17.2 Can Soldering

7.17.2.1 Process Description

Side seams of cans are soldered on a machine consisting of a solder-coated roll operating in a bath of molten solder, typically containing 98 percent lead. After soldering, excess is wiped away by a rotating cloth buffer, which creates some dust (Table 7.17-1).[3]

7.17.2.2 Emissions and Controls

Hoods, exhaust ducts and mechanical cyclones (Table 7.17-2). collect the large flakes generated at the wiping station, but some dust escapes in the form of particles 20 microns or smaller, with a lead content of 3 to 38 percent. Maintaining a good flux cover is the most effective means of controlling lead emissions from the solder batch. Low energy wet collectors or fabric filters can also control lead emissions from can soldering.

7.17.3 Cable Covering

7.17.3.1 Process Description

About 90 percent of the lead cable covering produced in the United States is lead cured jacketed cables, and 10 percent is on lead sheathed cables. In preparation of the former type, an unalloyed lead cover applied in the vulcanizing treatment during the manufacture of rubber-insulated cable must be stripped from the cable and remelted.

Lead coverings are applied to insulated cable by hydraulic extrusion of solid lead around the cable. Molten lead is continuously fed into an extruder or screw press, where it solidifies as it progresses. A melting kettle supplies lead to the press.

Table 7.17-1 EMISSION FACTORS FOR MISCELLANEOUS SOURCES[a]

(EMISSION FACTOR RATING: C)

Process	PARTICULATE EMISSION FACTOR		LEAD EMISSION FACTOR		References
	Metric	English	Metric	English	
Type metal production	0.4 kg/10^3 kg Pb proc[b]	0.7 lb/ton Pb proc[b]	0.13 kg/10^3 kg Pb proc	0.25 lb/ton Pb proc	2,7
Can soldering	0.8 x 10^6 g/10^6 baseboxes prod[c]	0.9 ton/10^6 baseboxes prod[c]	160 kg/10^6 baseboxes prod[f]	0.18 ton/10^6 baseboxes prod	7
Cable covering	0.3 kg/10^3 kg Pb proc[d]	0.6 lb/ton Pb proc[d]	0.25 kg/10^3 kg Pb proc	0.5 lb/ton Pb proc	3,5,7
Metallic lead products					
Ammunition	e	e	$\leq$0.5 kg/10^6 kg Pb proc	1.0 lb/10^3 ton Pb proc	3,7
Bearing metals	e	e	negligible	negligible	3,7
Other sources of lead	e	e	0.8 kg/10^3 kg Pb proc	1.5 lb/ton Pb proc	3,7

[a] Proc = processed; prod = produced

[b] Calculated on the basis of 35 percent of the total (Reference 1).

[c] Reference 7, pp. 4-297 and 4-298

[d] Reference 7, p. 4-301

[e] Data not available.

[f] Basebox = 20.23 m^2 (217.8 ft^2), standard tin plate sheet area.

7.17.3.2 Emissions and Controls

The melting kettle is the only source of atmospheric lead emissions, and it is generally uncontrolled.[4] Average particle size is approximately 5 microns, with a lead content of about 70 to 80 percent.[3,5]

Cable covering processes do not usually include particulate collection devices, although fabric filters, rotoclone wet collectors and dry cyclone collectors can reduce lead emissions (Table 7.17-2). Lowering and controlling the melt temperature, enclosing the melting unit and using fluxes to provide a cover on the melt can also minimize emissions.

7.17.4 Metallic Lead Products

7.17.4.1 General

Lead is consumed and emitted in the manufacture of ammunition, bearing metals and other lead products. Lead used in the manufacture of ammunition is melted and alloyed before it is cast, sheared, extruded, swaged or mechanically worked. Some lead is also reacted to form lead azide, a detonating agent. Lead is used in bearing manufacture by alloying it with copper, bronze, antimony and tin.

Other lead products include terne metal (a plating alloy), weights and ballasts, caulking lead, plumbing supplies, roofing materials, casting metal foil, collapsible metal tubes and sheet lead. Lead is also used for galvanizing, annealing and plating. It is usually melted and cast prior to mechanical forming operations.

7.17.4.2 Emissions and Controls

Little or no air pollution control equipment is currently used by manufacturers of metallic lead products.[6] Emissions from bearing manufacture are negligible, even without controls.[3]

Table 7.17-2. CAN SOLDERING AND CABLE COVERING CONTROL EFFICIENCIES

Process	Control	Percent Reduction
Can Soldering	Mechanical cyclone	75 +
Cable Covering	Fabric filter	99.9
	Rotoclone wet collector	75-85
	Dry cyclone collector	45 +

[a]Reference 7

References for Section 7.17

1. N.J. Kulujian, Inspection Manual for the Enforcement of New Source Performance Standards: Portland Cement Plants, EPA Contract No. 68-02-1355, PEDCo-Environmental Specialists, Inc., Cincinnati, OH, January 1975.

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8.10 CONCRETE BATCHING

Charles Masser

8.10.3 Fugitive Emission Factors

Potential sources of fugitive particulate emissions from concrete batching are shown in Table 8.10-2, along with the corresponding emission factors.

Particle size characteristics of the dust vary according to the grade of cement. A range of 10 to 20 percent by weight >5 μm is typical for the various grades of cement. The dust generated from dry concrete batching plants has characteristics similar to those of the cement dust discussed for wet concrete batching plants.

Table 8.10-2. POTENTIAL UNCONTROLLED FUGITIVE EMISSION FACTORS FROM CONCRETE BATCHING PROCESS (EMISSION FACTOR RATING: E)

TYPE OF OPERATION	PARTICULATES[a]	
	lb/ton	kg/MT
Transfer of sand and aggregate[b] to elevated bins	0.04	0.02
Cement unloading to elevated[c] storage silos	0.23	0.118
Weight hopper loading of cement, sand and aggregate[c]	0.23	0.118
Mixer loading of cement, sand, aggregate (central mix plant)[b]	0.02	0.01
Loading of transit mix truck[b]	0.02	0.01
Loading of dry-batch truck[b]	0.04	0.02

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[a]Factors expressed in units per unit of material handled.

[b]Engineering judgement based on observations and emission tests on similar controlled sources.

[c]Reference 5. From testing of mechanical unloading to hopper and subsequent transport of cement on enclosed bucket elevator to elevator bins with a fabric sock over the bin vent.

Reference for Section 8.10

5. Personal communication from T.R. Blackwood, Monsanto Research Corporation, Dayton, OH, to John M. Zoller, PEDCo-Environmental, Inc., Cincinnati, OH, 18 October 1976.

10.4 WOODWORKING OPERATIONS

Charles Masser

10.4.3 Fugitive Emission Factors

Since most woodworking operations control emissions out of necessity, fugitive emissions are seldom a problem. However, the wood waste storage bins are a common source of fugitive emissions. Table 10.4-1 shows these emission sources and their corresponding emission factors.

Information concerning size characteristics is very limited. Data collected in a western red cedar furniture factory equipped with exhaust ventilation on most woodworking equipment showed most suspended particles in the working environment to be less than 2 μm in diameter.[7]

Table 10.4-2. POTENTIAL UNCONTROLLED FUGITIVE PARTICULATE EMISSION FACTORS FOR WOODWORKING OPERATIONS

(EMISSION FACTOR RATING: E)

Type Of Operation	Particulates[a]	
	lb/ton	kg/MT
Wood waste storage bin vent[b]	1.0	0.5
Wood waste storage bin loadout[b]	2.0	1.0

[a]Factors expressed as units per unit weight of wood waste handled.

[b]Engineering judgment based on plant visits.

Additional Reference for Section 10.4

7. Lester V. Cralley, et al., Industrial Environmental Health, the Worker and the Community, Academic Press, New York and London, 1972.

APPENDIX E

COMPILATION OF LEAD EMISSION FACTORS

INTRODUCTION

Lead was not involved as a specific pollutant in the earlier editions and supplements of AP-42. Since a National Ambient Air Quality Standard for lead has been issued, it has become necessary to determine emission factors for lead, and these are given in Table E-1. The AP-42 Section number given in this table for each process corresponds to the pertinant section in the body of the document.

Lead emission factors for combustion and evaporation from mobil sources require a totally different treatment, and they are not included in this Appendix.

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Table E-1. UNCONTROLLED LEAD EMISSION FACTORS

AP-42 Section	Process	Emission Factor[a,b] Metric	English	References
1.1	Bituminous Coal Combustion (all furnace types)	0.8 (L) kg/10^6 kg (Average L = 8.1 ppm)	1.6 (1) lb/10^3 ton	1,4-6
1.2	Anthracite Coal Combustion (all furnace types)	0.8 (L) kg/10^6 kg (Average L = 8.1 ppm)	1.6 (L) lb/10^3 ton	1,4-6
1.3	Residual Fuel Oil Combustion (all boiler types)	0.5 (L) kg/$10^3 m^3$ (Average L = 1.0 ppm)	4.2 (L) lb/10^6 gal	1,7,8
1.3	Distillate Fuel Oil Combustion (all boiler types)	0.5 (L) kg/$10^3 m^3$ (Average L = 1.0 ppm)	4.2 (L) lb/10^6 gal	1,7,8
1.7	Lignite Combustion (all boiler types)	5-6 kg/10^6 kg	10-11 lb/10^3 tons	2
1.11	Waste Oil Combustion	4.8 (P) kg/m^3 (Average P - 1.0 percent)	40 (P) lb/10^3 gal	8,18,51,52
2.1	Refuse Incineration (municipal incinerator)	0.2 kg/10^3 kg chgd	0.4 lb/ton chgd	1,3,9-11
2.5	Sewage Sludge Incineration (wet scrubber controlled)			
	Multiple Hearth	.01-.02 kg/10^3 kg chgd	.02-.03 lb/ton chgd	3,12
	Fluidized Bed	.0005-.002 kg/10^3 kg chgd	.001-.003 lb/ton	3,12

Table E-1. UNCONTROLLED LEAD EMISSION FACTORS (CONTINUED)

AP-42 Section	Process	Emission Factor[a,b] Metric	English	References
5.22	Lead Alkyl Production			
	Electrolytic Process	0.5 kg/10^3 kg prod	1.0 lb/ton prod	1,3,53
	Sodium-Lead Alloy Process			
	Recovery Furnace	28 kg/10^3 kg prod	55 lb/ton prod	1,53,54
	Process Vents,TEL	2 kg/10^3 kg prod	4 lb/ton prod	1
	Process Vents, TML	75 kg/10^3 kg prod	150 lb/ton prod	1
	Sludge Pits	0.6 kg/10^3 kg prod	1.2 ton/ton prod	1
7.2	Metallurgical Coke Manufacturing	.00018 kg/10^3 kg coal chgd	.00035 lb/ton coal chgd	1,13,14

Table E-1. UNCONTROLLED LEAD EMISSION FACTORS (CONTINUED)

AP-42 Section	Process	Emission Factor[a,b] Metric	Emission Factor[a,b] English	References
7.3	Primary Copper Smelting			
	Roasting	1.2 (P) kg/10^3 kg conc (Average P - 0.3 percent)	2.3 (P) lb/ton conc	1
	Smelting (reverberatory furnace)	0.8 kg/10^3 kg conc	1.7 lb/ton conc	1,15,17
	Converting	1.3 kg/10^3 kg conc	2.6 lb/ton conc	1,15,16, 18
7.4	Ferroalloy Production - Electric Arc Furnace (open)			
	Ferrosilicon (50 %); FeSi	0.15 kg/10^3 kg prod	0.29 lb/ton prod	20
	Silicon Metal	0.0008 kg/10^3 kg prod	0.0016 lb/ton prod	1,19
	Silico-Manganese	0.43 kg/10^3 kg prod	0.85 lb/ton prod	1,21
	Ferro-Manganese(standard)	0.2 kg/10^3 kg prod	0.4 lb/ton prod	1,3
	Ferrochrome-Silicon	0.04 kg/10^3 kg prod	0.08 lb/ton prod	20
	High Carbon Ferrochrome	0.17 kg/10^3 kg prod	0.34 lb/ton prod	20
7.4	Ferroalloy Production - Blast Furnace	1.9 kg/10^3 kg prod	3.7 lb/ton prod	1,3

Table E-1. UNCONTROLLED LEAD EMISSION FACTORS (CONTINUED)

AP-42 Section	Process	Emission Factor[a,b] Metric	Emission Factor[a,b] English	References
7.5	Iron and Steel Production			
	Sintering (windbox + vent discharges)	0.0067 kg/10^3 kg sinter	0.013 lb/ton sinter	1,23,24
	Blast Furnace (for mixed charge)	0.062 kg/10^3 kg Fe	0.124 lb/ton Fe	1,23
	Open Hearth			
	Lancing	0.1 kg/10^3 kg steel	0.2 lb/ton steel	3,26,27
	No Lancing	0.2 kg/10^3 kg steel	0.5 lb/ton steel	3,26,27
	Basic Oxygen Furnace (BOF)	0.1 kg/10^3 kg steel	0.2 lb/ton steel	1,23,25
	Electric Arc Furnace			
	Lancing	0.11 kg/10^3 kg steel	0.22 lb/ton steel	1,28
	No Lancing	0.09 kg/10^3 kg/steel	0.18 lb/ton steel	1
7.6	Primary Lead Smelting			
	Ore Crushing and Grinding	0.15 kg/10^3 kg ore	0.3 lb/ton ore	29

Table E-1. UNCONTROLLED LEAD EMISSION FACTORS (CONTINUED)

AP-42 Section	Process	Emission Factor[a,b] Metric	English	References
	Sintering	4.2-170 kg/10^3 kg Pb prod	8.4-340 lb/ton Pb prod	1,21,22, 30-33
	Blast Furnace	8.7-50 kg/10^3 kg Pb prod	17.5-100 lb/ton Pb prod	1,30,32, 33,35,36,
	Dross Reverberatory Furnace	1.3-3.5 kg/10^3 kg Pb prod	2.6-7.0 lb/ton Pb prod	1,18,30, 34,36
7.6a	Lead Bearing Ore Crushing and Grinding			
	Lead Ores (Section 7.6)	0.15 kg/10^3 kg proc	0.3 lb/ton proc	1,3,29, 59,60
	Zn, Cu-Zn, Cu Ores	0.006 kg/10^3 kg proc	0.012 lb/ton proc	1,3,29, 59,60
	Pb-Zn, Pb-Cu, Cu-Pb-Zn Ores	0.06 kg/10^3 kg/proc	0.12 lb/ton proc	1,3,29, 59,60
7.7	Zinc Smelting			
	Ore Unloading, Storage, Transfer	1-2.9 kg/10^3 kg ore	2.0-5.7 lb/ton ore	37
	Sintering	13.5-25 kg/10^3 kg ore	27-50 lb/ton ore	1,30,38

Table E-1. UNCONTROLLED LEAD EMISSION FACTORS (CONTINUED)

AP-42 Section	Process	Emission Factor [a,b] Metric	English	References
	Horizontal Retorts	1.2 kg./10^3 kg ore	2.4 lb/ton ore	1,30,38
	Vertical Retorts	2-2.5 kg/10^3 kg ore	4.5 lb/ton ore	1,30, 38
7.9	Secondary Copper Smelting and Alloying			
	Reverberatory Furnace (high lead alloy 58% Pb)	25 kg/10^3 kg ore	50 lb/ton ore	1,26,39-41
	Red and Yellow Brass (15% Pb)	6.6 kg/10^3 kg ore	13.2 lb/ton ore	1,26,39-41
	Other Alloys (7% Pb)	2.5 kg/10^3 kg ore	5 lb/ton ore	1,26, 39-41
7.10	Gray Iron Foundries			
	Cupola	0.05-0.6 kg/10^3 kg prod	0.1-1.1 lb/ton prod	1,3,26, 42,43
	Reverberatory Furnace	0.006-0.7 kg/10^3 kg prod	0.012-0.14 lb/ton prod	1
	Electric Induction Furnace	0.005-.05 kg/10^3 kg prod	0.009-0.1 lb/ton prod	1
7.11	Secondary Lead Smelting			
	Reverberatory Furnace	27 kg/10^3 kg Pb prod	53 lb/ton Pb prod	1,38,42-46
	Blast Cupola Furnace	28 kg/10^3 kg Pb prod	56 lb/ton Pb prod	38,42-46

Table E-1. UNCONTROLLED LEAD EMISSION FACTORS (CONTINUED)

AP-42 Section	Process	Emission Factor[a,b] Metric	English	References
	Refining Kettles	0.1 kg/10^3 kg Pb prod	0.21 lb/ton Pb prod	46
7.15	Storage Battery Production (total)	8 kg/10^3 batteries	17.7 lb/10^3 batteries	1,55-58
	Grid Casting	0.4 kg/10^3 batteries	0.9 lb/10^3 batteries	1,55-58
	Lead Oxide Mill (baghouse outlet)	0.05 kg/10^3 batteries	0.12 lb/10^3 batteries	1,55-58
	Three-process Operations[c]	6.6 kg/10^3 batteries	14.6 lb/10^3 batteries	1,55-58
	Lead Reclaim Furnace	0.35 kg/10^3 batteries	0.77 lb/10^3 batteries	1,55-58
	Small Parts Casting	0.05 kg/10^3 batteries	0.10 lb/10^3 batteries	1,55-58
7.16	Lead Oxide and Pigment Production			
	Barton Pot (baghouse outlet)	0.22 kg/10^3 kg/prod	0.44 lb/ton prod	1,61,62
	Calcining Furnace	7 kg/10^3 kg prod	14 lb/ton prod	61
	Red Lead (baghouse outlet)	0.5 kg/10^3 kg prod	0.9 lb/ton prod	1,54
	White Lead (baghouse outlet)	0.28 kg/10^3 kg prod	0.55 lb/ton prod	1,54
	Chrome Pigments	0.065 kg/10^3 kg prod	0.13 lb/ton prod	1,54

Table E-1. UNCONTROLLED LEAD EMISSION FACTORS (CONTINUED)

AP-42 Section	Process	Emission Factor[a,b] Metric	English	References
7.17	Miscellaneous Lead Products			
	Type Metal Production	0.13 kg/10^3 kg Pb prod	0.25 lb/ton Pb proc	1,63
	Can Soldering	160 kg/10^6 baseboxes[d] prod	0.18 ton/10^6 baseboxes prod	1
	Cable Covering	0.25 kg/10^3 kg proc	0.5 lb/ton Pb prod	1,3,64
	Metallic Lead Products			
	Ammunition	0.5 kg/10^6 kg Pb prod	1.0 lb/10^3 ton Pb prod	1,3
	Bearing Metals	negligible	negligible	1,3
	Other Sources of Lead	0.8 kg/10^3 kg Pb prod	1.5 lb/ton Pb proc	1,3
8.6	Portland Cement Manufacturing			
	Dry Process (total)	0.08 kg/10^3 kg prod	0.15 lb/ton prod	1,47,48
	Kiln/cooler	0.06 kg/10^3 kg prod	0.11 lb/ton prod	1,47,48
	Dryer/grinder	0.02 kg/10^3 kg prod	0.04 lb/ton prod	1,47,48
	Wet Process (total)	0.06 kg/10^3 kg prod	0.12 lb/ton prod	1,47,48
	Kiln/cooler	0.05 kg/10^3 kg prod	0.10 lb/ton prod	1,47,48
	Dryer/grinder	0.01 kg/10^3 kg prod	0.02 lb/ton prod	1,47,48

Table E-1. UNCONTROLLED LEAD EMISSION FACTORS (CONTINUED)

AP-42 Section	Process	Emission Factor[a,b] Metric	English	References
8.13	Glass Manufacturing (Lead glass; 23% Pb in particulate)	2.5 kg/10^3 kg glass	5 lb/ton prod	1,49
11.2	Fugitive Dust Sources (Re-entrained from paved roadway)	0.02 g/vehicle km	0.00007 lb/vehicle mi	50

[a] The letter L indicates that the ppm lead in the coal or fuel oil should be multiplied by the value given in order to obtain the emission factor for the fuel. The letter P similary indicates that the percent lead in the ore being processed should be multiplied by the value given in the table in order to obtain the emission factor.

[b] Abbreviations: chgd = charged
conc = concentrate
prod = produced
proc = processed

[c] Stacking, lead burning, and battery assembly.

[d] Basebox = 20.23 m^2 (217.8 $ft.^2$), standard tin plate sheet area.

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